GREEN INTERVENTIONS TO MITIGATE THE EFFECT OF URBAN HEAT ISLAND

A DISSERTATION

Submitted in partial fulfillment of the

requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

DISASTER MITIGATION AND MANAGEMENT

By

JAGRATI SEHGAL

CENTRE OF EXCELLENCE IN DISASTER MITIGATION AND MANAGEMENT

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

ROORKEE - 247667 (INDIA)

MAY, 2018

CANDIDATE'S DECLARATION

I hereby declare that the work carried out in this dissertation titled **"GREEN INTERVENTIONS TO MITIGATE THE EFFECT OF URBAN HEAT ISLAND"** is submitted in partial fulfilment of the requirement for the award of the degree of **"Master of Technology"** in CENTRE OF EXCELLENCE IN DISASTER MITIGATION AND MANAGEMENT, **Indian Institute of Technology, Roorkee, India,** under the supervision of **Dr. Mahua Mukherjee,** Head CoEDMM, (Associate Professor) Department of Architecture and Planning, IIT Roorkee, India & **Prof. Dr.-Ing. Ferdinand Ludwig**, Chair of Green Technologies in Landscape Architecture, Technical University of Munich, Germany, is an authentic record of my work done during the Spring semester of 2017-18. I have not submitted the matter embodied in this report for the award of any other degree or diploma.

Date:

Place: Roorkee **JAGRATI SEHGAL**

CERTIFICATION

This is to certify that the above statement made by the candidate is correct to the best of our knowledge and belief.

Dr. Mahua Mukherjee
Head, CoEDMM
Associate Professor
Department of Architecture & Planning
Indian Institute of Technology Roorkee,
Roorkee 247667, India

Prof. Dr.-Ing. Ferdinand Ludwig
Associate Professor
Chair of Green technologies in
Landscape Architecture
Technical University of Munich
Munich - 85354, Germany

ACKNOWLEDGEMENT

Writing this thesis has been engaging and encouraging. I would like to thank all the people who have contributed their part to the study.

I would like to express my sincere and deepest gratitude to my guide & **Head of CoEDMM**, **Dr. Mahua Mukherjee**, Associate Professor in Department of Architecture and Planning, for her meticulous guidance, patience and suggestions during my studies. I express my deep sense of gratitude and respectful regards to my supervisor **Prof. Dr. -Ing. Ferdinand Ludwig,** Professor for Green Technology in Landscape Architecture at Technical University Munich**,** Germany, for his invaluable guidance and healthy criticism during my studies.

I would like to thank **Dr. Kamal Jain**, Chairman, Academic Program Committee CoEDMM & other jury members for their valuable criticism during the juries which helped me to achieve a better study. I owe my very special thanks to, **Dipl. -Ing. Ute Vees,** for her suggestions, comments and efforts to make this study happen.

I am thankful to all the facilities associated with the Centre of Excellence in Disaster Mitigation & Management, IIT Roorkee. I acknowledge the DAAD Fellowship (IIT Master Sandwich Scholarship) for providing me an opportunity to study at the Technical University of Munich.

I express my heartfelt thanks to my family members for their blessings and encouragement. I owe my very special thanks to Col. Preet Pal Singh Dhillon for his support & encouragement.

My very special thanks to all my friends, especially Sanjay, Prerna, Atul, Ila, Dhanu and Deepak for their support and encouragement during the work.

Date:

Place: Roorkee **JAGRATI SEHGAL**

ABSTRACT

Due to undergoing urbanization trend worldwide, distance between city inhabitants and nature is increasing. Urban areas being economically diversified attract ample of migrants making for a burgeoning population. This is more prevalent in the developing countries such as India. Gurugram, a city in the Indian state of Haryana and a part of National Capital Region (NCR) of India has been going through rapid urbanization in the past decade. The paper is concerned about the notorious effect of urbanization, that is the heating of the local climate in comparison to the surrounding rural areas, creating a phenomenon known as the 'Urban Heat Island' (UHI). Physical Characteristics of the city and the increasing graph of population are the major causes of UHI, which in turn is increasing energy demand and making the cities most vulnerable.

The aim of the study is to integrate green interventions as remedial measures to mitigate impact of UHI. Green interventions are proving themselves factual in maintaining urban energy balance by dissipating the extra amount of heat and in making urban environment resilient. A case study methodology is adopted for the study. This study includes understanding the role of green interventions in mitigating the effect of UHI and to compare the executed interventions in two of the cases of Munich and Stuttgart, two major cities in Germany. The focus of the study is to find out the best possible interventions to implement in specific regions of Study (Gurugram). Urban space is more than a collection of buildings and incorporate the factors responsible for causing UHI. Therefore, there is necessity of generating urban spaces in a manner which are themselves sufficiently resilient. The idea of the study is to integrate green space in urban areas to make the cities more sustainable and resilient.

Contents

List of Figures

Table of Contents

CHAPTER 1. Introduction

1.1 Preface

Synergizing effect of urbanization and Climate Change is having great impact on urban temperatures. Urbanization adversely impacts environmental conditions of an area by modification of physical and chemical properties of the atmosphere. Urban areas are reasonably diversified and thus, attracts migrants in large number, which results in burgeoning population. Urban areas are home for more than half of the world population. This condition is becoming more prevailing in the countries where development is the phase. The character of modern days cities such as less vegetation, the majority of hard surfaces, and anthropogenic heat sources are the factors responsible for the happening of the urban heat island. Use of green interventions to mitigate the effect of Urban Heat Island would be effective to converse the way.

1.2 Need of the Study

The city of Gurugram is economically very significant for the National Capital Region (NCR) in India. During the last decade rapid urbanization has completely changed the land use of the city and resulted in several 'Heat Island pockets'. The population of the city from 90,000 in 1991 has grown to 876,824 in 2011 (Census of India, 2011). This rapid urbanization has also expanded the city spatially causes shortage of housing. This increases demand for infrastructure facilities in the city and gives rise to a number of causes for increment of air temperature in the city.The average temperature of the city has risen during this period and it is predicted to be further going to increase over time which is a serious matter of concern. Thus the study of Urban Heat Island in the city of 'Gurugram' will be of immense importance. As the open land is not much more available in the city, green interventions options in neighborhood scale will be of importance and can be an effective measure to mitigate the effect of UHI.

1.3 Aim

To integrate green interventions as remedial measures to mitigate impact of UHI in Gurugram region of NCR.

1.4 Objectives

i. To understand the role of Green Interventions in mitigating UHI effect.

ii. To conduct a comparative case study of Munich and Stuttgart to learn applicable lessons.

iii. To come up with measures to control the negative impacts of UHI from the lessons learnt and to implement the strategy of green intervention in Gurugram.

1.5 Methodology

The work shall be divided into three stages - the literature studies, the comparative case studies and the site study. The final proposal will be in the form of green interventions which can be implemented on site to mitigate the effect of UHI.

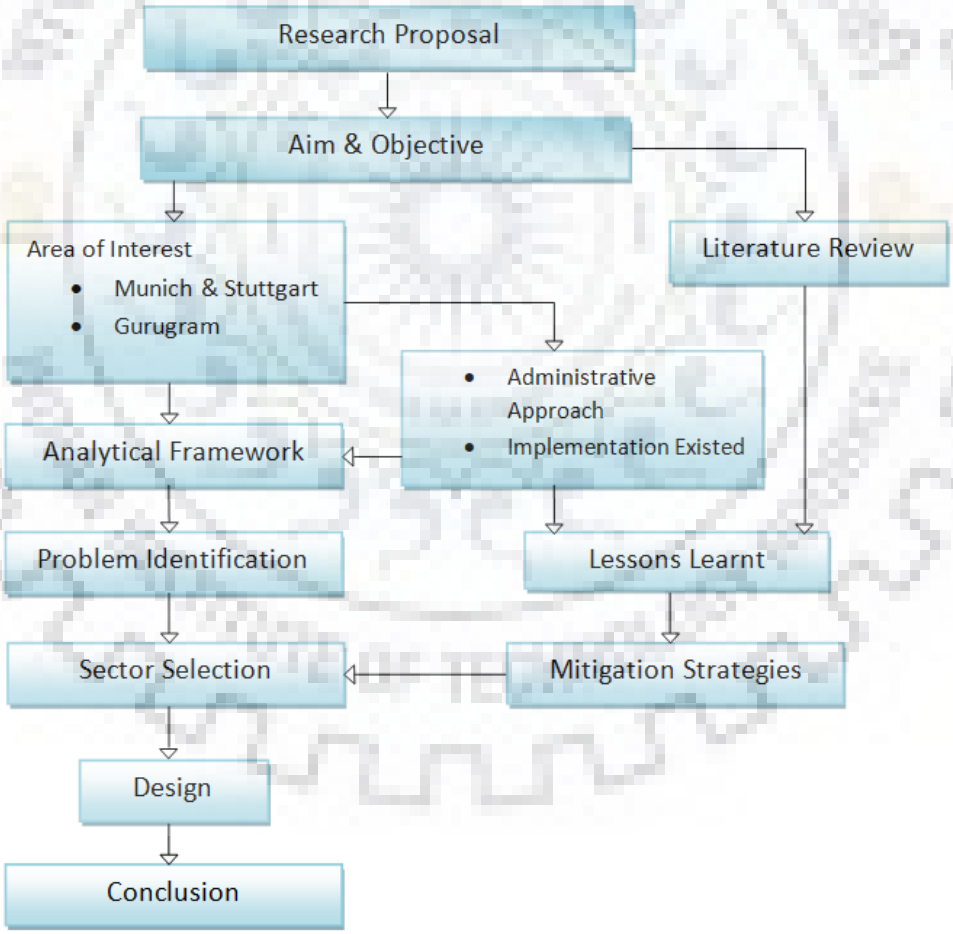


Figure 1 - Methodology Flow Chart

1.6 Scope

The research study will come out with quantification of strategies to deal with and mitigate the effect of UHI with the help of Green Interventions in Gurugram. However, the scale of the city is too large and hence a few small pockets in the city will be identified for the research purpose.

1.6.1 Limitation

The study cannot suggest implementation specifically for the whole city. Due to the restricted amount of time, the small part of the city is selected and strategies have been applied to that part. Similarly, they can be applied in other parts of the city depending on the specific area.

CHAPTER 2. Literature Review

2.1 General

This chapter contains various literature required to conduct the study. The first part includes the description of UHI and its causes, formation, types and impacts. Further, it explains that how the impacts are causing risk to the society. The next part discussed about mitigation strategies and the role of green spaces as mitigation measures.

2.2 Urban Heat Island (UHI)

'Heat Island' refers to the warmth of a place when compared to its countryside, where the temperature of the urban region is higher than that of the rural region. UHI is atmospheric modification which can vary from a few meters to kilometers. Typically, the temperature difference between urban and rural areas ranges from 3-5°C during the day. However, at night the difference can reach as high as 12°C due to the slow radiation of heat from urban surfaces (Environmental Protection Agency, 2008). As the urban region continues to develop, simultaneously changes occur in the landscape of cities. Changes in the urbanscape, conversion of vegetated and permeable land and forms of urban infrastructure are replacing vegetative areas. These changes are the reasons for urban regions to accumulate more heat in comparison to their rural surroundings, forming a "Heat Island". Figure 2 shows that how everything is accumulating in the city center and forcing the air temperature to rise above.

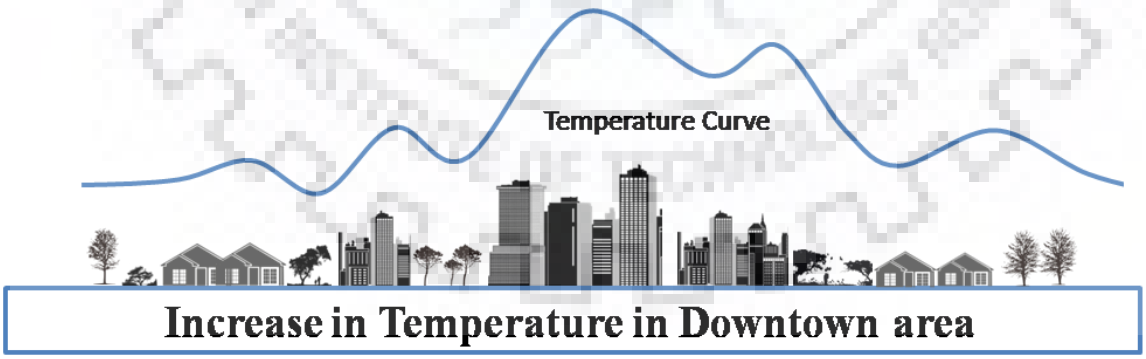


Figure 2 - Image showing a Temperature increase in the city centre

2.2.1 Causes of UHI

World urbanization has grown rapidly since the Second World War. Nowadays, cities have around half of the world's population lived in. In addition, it is anticipated that inhabitation in cities will reach 60% by 2030 and 70% by 2050. The evolution of urban regions is affecting climate of the place and the quality of life. The change of the land surface and replacement of vegetation by expansively built surfaces (typically paved roads and building's surfaces) are the main causes of UHI.

The UHI arises from anthropogenic factors as well as from natural factors. Humans are imposing a greater impact on UHI basically through the approach of planning such as the conversion of vegetated land, building urban infrastructures etc. However, there are some natural factors also that cannot control by human such as meteorological conditions that can also modify the strength of the UHI.

1. Vegetation Removal – The primary and the major factor responsible for the contribution of UHI is the loss of landscaped areas. Vegetation in a landscaped area helps ecosystem through the process of evapotranspiration. Trees play a big role in providing shading, especially for pedestrians and helps in preventing solar energy from being absorbed. Evapotranspiration helps in cooling the spaces by 2-8°C as compared to surrounding areas and thus affect the cooling process (Taha 1997). Therefore, when vegetation and green areas are removed, the amount of solar emission which was supposed to reflect back enters into the atmosphere and thus, results in warming of ambience.

2. Urban Surface/Geometry – The urban geometry can dominate the effect of UHI by changing the amount of absorbed and reflected solar radiation. The built up areas can increase the amount of absorbed incoming radiation from the sun. In the absence of heavy built up areas, the incoming radiation gets absorbed and reflected back into the atmosphere. Buildings are interfering the process of absorption and reflection and causing reflections of radiations multiple times by more than one surface. Narrow streets and dense high rise buildings can interfere with the air flow within the city (Hoyano et al., 1999). The result of which is an accumulation of extra amount of heat which gets absorbed and is not able to reflect back and thus, forming the cause of UHI.

3. Low albedo Material – Due to decrement in green cover, the increament in urban infrastructure occurs. Urbanscapes are primarily made up of hard surfaces having low albedo. Most of the spaces in urban areas are made up of materials which are causing UHI by varying the way of how solar radiation is absorbed, emitted and reflected. The key property of material that influence the reflection of solar radiation from giving surface is measured in terms of albedo. Use of low albedo material has resulted in increasing temperature up to 20K (Santamouris, M, 2013).

In addition, with albedo value, the emissivity of the material is also a factor which is responsible for radiation of heat from the surface. Those surfaces which contain materials with low emissivity releases heat slowly, and therefore, cause areas to hold heat and increase air temperatures.

4. Anthropogenic Heat – The waste heat produced due to human activity gets released into the atmosphere and disturb the thermal balance of the area. Anthropogenic heat includes an extra amount of heat produced from industrial process, chemical process, electrical appliances, from vehicles, air conditioning systems, ventilation and heating system etc.

The anthropogenic heat has mostly effected the surface air temperature and thus is the major source for creating UHI. Anthropogenic heat can increase the air temperature by 20 - 30°C (Taha 1997). In highly dense areas, the heat releases are mostly greater than the solar input. Heat produced depends on a particular place, the living requirements, use of energy and transportation.

5. Weather Conditions – Some of the natural factors can exert temporary effects on the creation of UHI. Meteorological patterns, geographic locations and topography of the place are related variables that matters. These variables show changes with respect to the amount of UHI. Previous research has shown that the intensity of UHI is minimum when wind speed is high and maximum when there is low wind and minimal cloud cover. Moving wind promotes the cooling of air by convection and maintains thermal balance, low wind speed reverses the condition and thus, creating warm environment. The UHI gets affected by the cloud cover and the wind speed and generally occurs when there is low wind speed and less cloud cover. (Oke 1982; Bonan 2008).

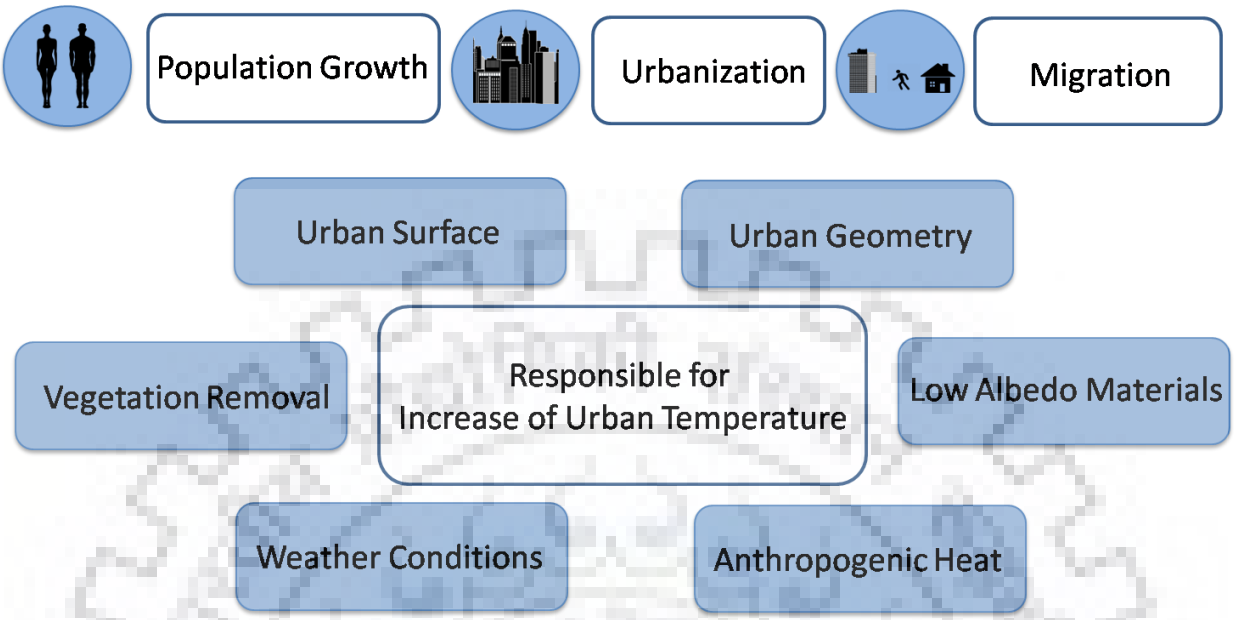


Figure 3 - Image showing factors responsible for causing UHI

2.2.2 Formation of UHI

Major Source of heat on our planet is the Sun. Added to it there are a number of man-made sources such as power plants, air conditioning machines, 2 & 4 wheelers, industrial processes, and other sources which are reasons for the generation of anthropogenic heat. Anthropogenic heat sources exist in the environment and effects instantly. However the part of solar emission warms the atmosphere directly.

The man made structures absorb and accumulate the remaining amount of solar radiations in the form of heat during the day. Afterwards, when environment cools down at night, the stored heat gets released back into the environment and heat the atmosphere indirectly.

The amount of solar energy which is absorbed and then released by urban structures depends on the physical properties of different urban surfaces and their form in urban landscapes, as well as climatic condition and regional meteorology (Oke, 1982; Sailor, D. J.; Lu, L. 2004) The higher amount of of non-reflective surfaces and a less proportion of green areas in the city provides a favorable condition for generating more and more urban heat islands. Materials such as stone,

concrete, and asphalt tend to trap heat at the surface (Landsberg, 1981) and less amount of green areas decreases heat lost due to evapotranspiration (Lougeay, Brazel, and Hubble, 1996) Landscape have a huge role in maintaining surface temperature, especially when the high moisture level is present.

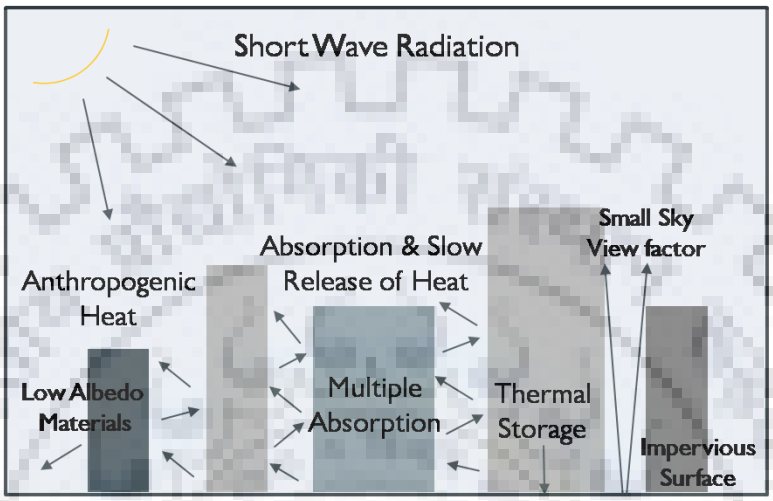


Figure 4 - Image Showing formation of Urban Heat Island

2.2.3 Types of UHI

The UHI is a measure of increased temperature in the air mainly close to the surface level in developed settlement in comparison with undeveloped surroundings. In actual Heat Island can also be measured at atmospheric level, which is further classified according to observation method. Although all different types of UHI are interrelated, still their process of study and observation desk is different.

There are following three types of Heat Island existed:

Surface heat island (SUHI)

Atmospheric heat island

Canopy layer heat island (CLHI)

Boundary layer heat island (BLHI)

1. Surface heat island (SHI) – The impact of the surface heat island is mainly visible in summer time. There is variation in magnitude of surface heat islands with the seasons, because of a change in weather and solar radiation. Temporal variation of the surface heat island is the common topic of having a conversation. It is maximum mainly during the day when emission through sun is creating major differences between dry, wet and vegetated spaces and can be mainly noticed in exposed surfaces like pavements and roof tops.

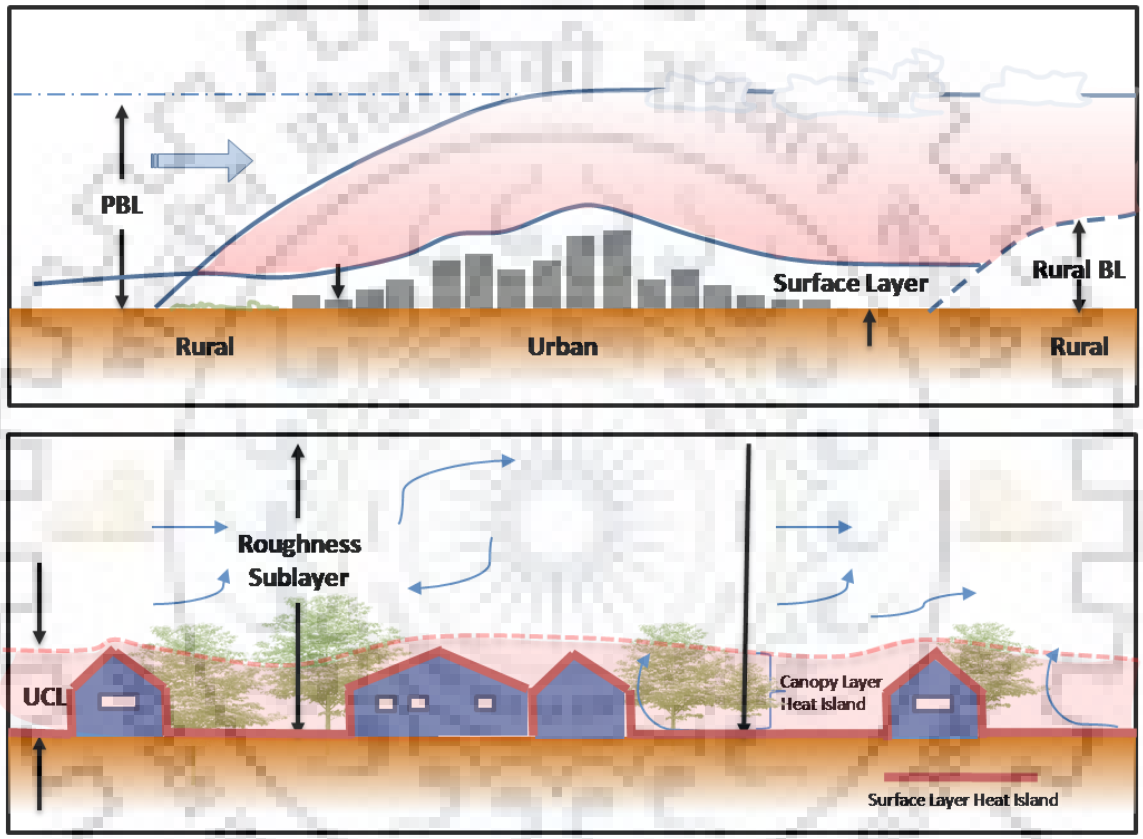


Figure 5 - Image showing UHI in different layers

2. Atmospheric heat island – The Atmospheric heat island can be defined a heated air in urban regions as compared to cooler air in rural region. This type of heat island is divided into two different types:

i. Canopy layer heat island (CLHI) – Canopy layer heat island existed near atmospheric layer below the canopy layer, i.e below the tops of trees and buildings. The canopy layer heat island is

known for local scale phenomenon. It is the most discussed phenomenon because of its relevance and accessibility to human activities. It is primarily a nocturnal process and happens because of the slow process of cooling in the urban region during the evening.

ii. Boundary layer heat island (BLHI) – Due to the extension of warmness of the city in the boundary layer, the boundary layer heat island existed. It is the less studied among all other types because of the experimental difficulties to probe the air at more height. But still some studied have been done with the help of helicopter, remote sensing, and tower studies. It is the local mesoscale process and is very less intensifies as compared to the canopy layer.

2.3 Impacts Causing Risk

UHI is affecting the environmental condition and hence the quality of life and is evident in urbanized areas. The existence of UHI in such regions is possessing several threats to living organisms and most important to humans and also effecting regional and global climate.

Though UHI has some positive impacts also but they are temporary such as increment in the duration of the plant growing season and improvement of thermal conditions, especially in cold climates and winters, and hence the major point of concern is negative effects which are worsening discomfort in summer season and causing impacts like increase in energy demand, impaired air and water quality, increase air pollutants, more amount of greenhouse gases, compromised human health etc.

1. **Air and Water Quality -** Increase in the amount of energy demand is contributing towards poor air quality and water quality arising mainly due to increased temperature. The water quality is degraded by thermal pollution happening because of surface urban heat islands. Pavements and surfaces where temperature reaches above 50°C those surfaces transfer the excess heat to storm water. This storm water when drains into the sewers, raises the temperature of water.

2. Human Health and Comfort – Core temperature of the human body is 37°C (98°F), therefore, functions of body work well at this temperature and above this temperature range, human body is at higher risk for illness related to heat and even though if not able to survive than in the worst case gets mortality. When the temperature of inner body rises, the potential severity of heat related illness increases. At some extent extreme heat can lead to discomfort among

humans. However, sometimes serious issues like loss of water and minerals take place. In an extreme case types of diseases like cardiovascular or respiratory disease, diabetes, renal disease, nervous system disorders, and emphysema can take place (Chan et al., 2007). UHI is increasing the adverse effect on health by increasing the air temperature above average, decreasing the ability of the body to stay cool. The illness can be in the form of heat cramps, heat enema, fainting, heat rash and exhaustion and heat stroke (Forkes, 2010).

3. Increased Energy Demand – Increase in air temperature, creating more warmer surfaces during both day and night and therefore increased energy demand. With every 1°C rise in temperature there is a simultaneous increase in 2-4% energy demand (Akbari, 2001). There is a further increase in energy demand because of the creation of urban infrastructure with high albedo materials which increases the amount of absorption of solar emission. Continuous use of air conditioning to keep buildings thermally stable and to maintain a comfortable environment inside results in increments of more demand of energy.

4. Adding Green House Gases – As UHI is increasing energy demand**,** to fulfil such demands, companies need to rely on fossil fuels due to which greenhouse gas emission and air pollutants are increasing and worsening the condition of the climate (Adinna, 2009). Air pollutants like nitrogen oxide and sulphur dioxide are very harmful for health and creates major air quality problems. More use of fossil fuels adds greenhouse gases in the atmosphere such as carbon dioxide, which is even more dangerous if exceeds than the limited amount.

5. Global Warming – Addition of greenhouse gases in the atmosphere gives rise to the problem of global warming and hence contributing to global climate change. Trapping of extra heat in the environment in terms of greenhouse gases, which leads to increase in the average temperature of the earth, results in global warming. Anthropogenic heat is mainly the cause for disturbing the energy balance in the urban areas (Cenedese and Monti, 2003; Offerle et al., 2006)

6. Extreme Weather Events –Extreme weather events can take place because of the accumulation of the extra amount of heat in the urbanscape. Events like hurricanes, storms and floods, etc. can happen. UHI influences rainfall patterns and lightening (Gedzelman et al., 2003; Rozoff et al., 2003; Childs and Raman, 2005). When air becomes warm it has more capacity to hold moisture and water and thus, it results in heavy precipitation, which sometimes turns out as unexpected heavy rainfall and becomes the reason for flash floods.

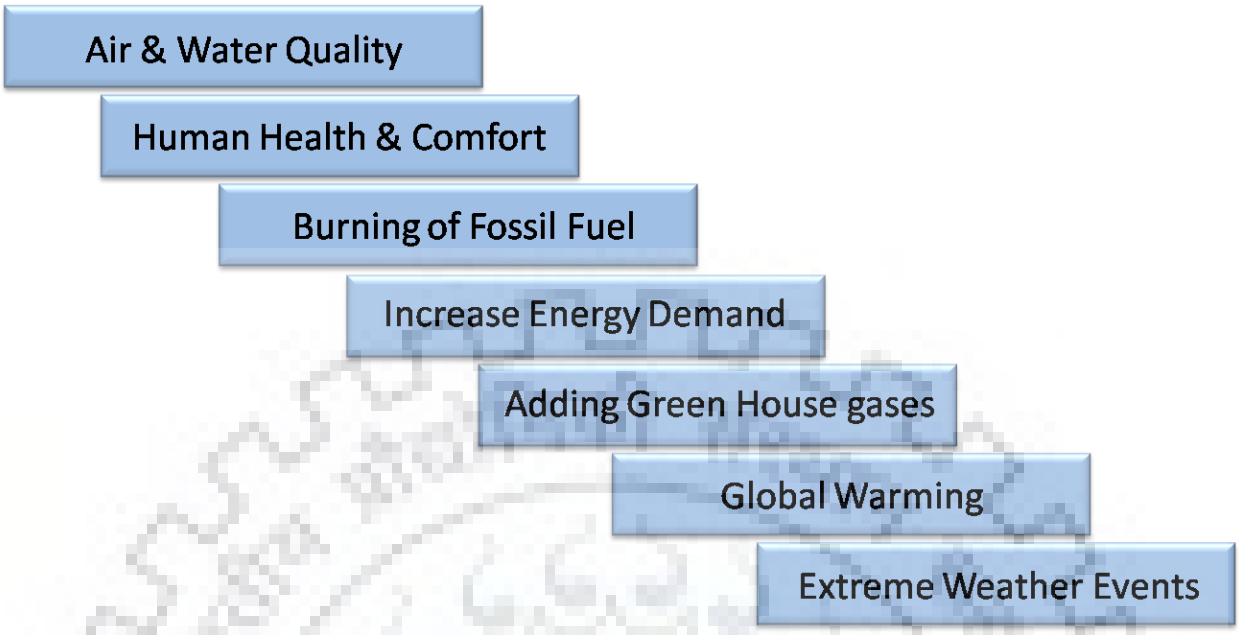


Figure 6 - Chart showing impacts of UHI

2.4 Mitigation Measures

Mitigation strategies are the actions taken to mitigate or reverse the effects of human activity on the environment. The Urban sheat island exists in both summer and winter seasons, but summertime effects get the major concern for mitigation process. The correct application of green intervention is an effective means to combat the effect of heat islands. Mitigation strategies mainly focused to reduce the intensity of the summertime heat island.

Mitigation Strategies will help to decrease the negative impacts of UHI like energy demand, air and water quality and most importantly health impacts. 20% of energy can be saved if mitigation strategies are implemented properly (Yamamoto, 2006). These strategies are planned in a way that they have abilities to reverse the main cause of producing heat island effect.

Different mitigation strategies are suggested by different experts in the field of urban planning, architecture, natural resource management and transportation. These mitigation strategies are providing result at both local and global scales. In addition to environmental benefits, these mitigation strategies, also helps in maintaining thermal balance of a place and also proves out to be significant to reduce the use of energy consumption.

a) Ground Vegetation - The use of vegetation is the most effective measure to reduce the UHI effect (Wilmers, F, 1988). Ground vegetation influences surface air temperature and helps in maintaining thermal balance by the process of evaporation. Grass over open land helps in providing low resistance to air flow, which might enhance cooling by convection (Bowler, 2010). One of the study shows that temperature over irrigated agricultural field is 3°C less than open terrain and another study shows that sports field with grass is 2°C cooler when compared to open land (Kurn, D., S. Bretz, B. Huang, and H. Akbari. 1994)

b) Urban Park - Based on studies conducted, it has been found out that urban park could reduce the air temperature of the surrounding area by 4°C (Oke, 1998; Jonsson, 2004; Zoulia, Santamouris, and Dimoudi 2009). Vegetation in park generates a phenomenon known as Park Cool Island, which have localized cooling effect in contrast with Urban Heat Island. (Shashua-Bar, Pearlmutter, and Erell 2009).

c) Street Trees - Temperature can be decreased by substantial value of planting trees. The studies conducted on the importance or maturity of trees have been found that areas under a mature tree in suburban area are 2 to 3°C cooler than the suburbs without the tree and another study found that peak air temperature in grooves of trees is 5°C less than it is over open land (Huang, J., H. Akbari, and H. Taha. 1990). Dense tree shade on the street with minimal traffic has the cooling effect of 2.2°C (Tsiros, 2010). Tree foliage can help in reduction of solar radiation by 60-90 % (Moufida, B.; Djamel, A, 2012).

d) Medians - Medians are central strips on roads, divide the road into two parts. These medians are vegetated with shrubs and plants helps in controlling increased dust pollutants and thus helps in keeping the air temperature minimum.

e) High Albedo Material - One of the strategy is to use high albedo materials on building facades exposed to solar radiation. Dark colour materials absorbs more sunlight and make the buildings warm while light coloured material with same insulation properties do get much warm because it reflects back the solar radiation (Akbari et al. 2001). One of the study shows the effect of roofing material of albedo value 0.20 and 0.60, where it has observed that the roof temperature dropped by 25°C for 0.60 as compared to that for 0.20 (Akbari et al. 1988). Thus a high albedo material has the effectiveness to play the role for UHI mitigation strategies.

f**) Pervious Pavements** - Impervious pavements don't allow water to infiltrate through it and 5thus the process of evaporation is not possible in this case (Sailor 2006). By the use of permeable pavement air temperature can be reduced up to some extent. Thus, repaving streets with cool paving materials is expected to lower urban air temperatures (Rosenfeld et al. 1998, Taha 1997). The use of pervious pavements can reduce air temperature by up to 20K (Santamouris 2013).

g) Water bodies - Increased amount of water bodies may reduce temperature due to their evaporative action and enhanced wind speed (Robitu et al. 2006). As the heat absorption capacity of water is high, it will help to reduce the air temperature. Flowing water has a larger cooling effect than stagnant water; dispersed water like from a fountain has the biggest cooling effect.

h) Green Roof - The 21% to 26% of the surface area in cities is comprised of roof surface (Wong, 2005) therefore, few green roofs over some buildings does not have a large effect on a local scale inspite in some special cases. Green roofs absorb heat and filter the air and keeps the air temperature low (Getter 2006). Green roof has various advantages if used over whole city such as it helps in removing dust particles from the air and also cleanse and retain storm water.

MITIGATION STRATEGIES	
a) Ground Vegetation	Enhance cooling by convection
b) Urban Park	Develops Park Cool island phenomenon
c) Street Trees	Reduce maximum solar radiation to reach the surface
d) Medians	Mainly control dust pollutants
e) High Albedo Material	By reflecting most of the solar radiation back
f) Pavements	Increase water filteration and thus maintains air temperature
g) Water Bodies	Flowing water effects more like in fountains and cascades etc.
h) Green & Cool Roof	Remove dust particles and retain storm water

Table 1 - List of common UHI mitigation measures

2.5 Role of Urban Green Spaces

There is no universal term exist for defining urban green space. They are the places which have natural settings and can be considered as the green space. From being open to use, they can also be very specific also. Most common urban green spaces are gardens, parks, riverside footpaths, green rooftops and so on.

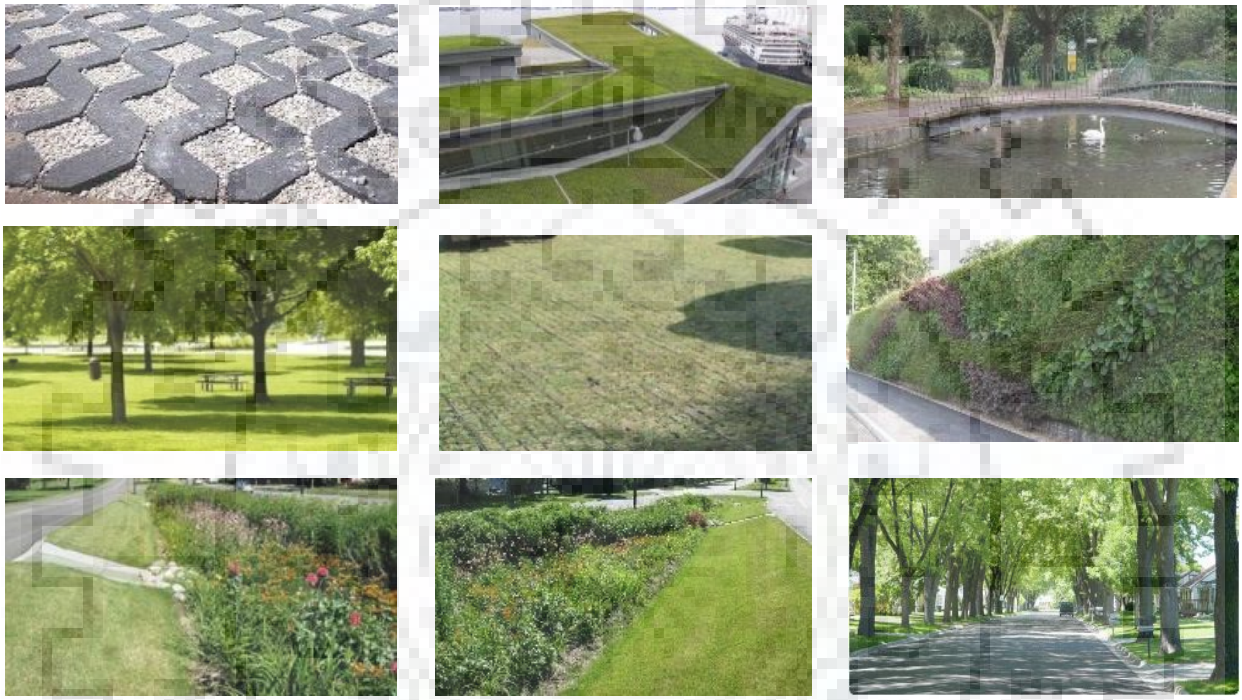


Figure 7- Images showing different forms of Urban Green Spaces

Creating new '**urban green space'** is a term used for applicability of green intervention in urban areas**,** which includes changing or improving of green space characteristics and functions, making of standard maintenance of green spaces which will provide positive effects on the environment, on physical activity / lifestyle, health and wellbeing.

Tree plantation has a significant contribution in maintaining the level of CO2 (Giguere, M, 2009) in the environment, as they directly use CO2 from the environment for the process of photosynthesis. Tree plantation helps in maintaining environment cool and thus reduce the demand for cooling, hence, minimize the level of CO2 in the atmosphere, which can be generated through power plants for producing energy.

Green Spaces provides ecosystem services and maintains thermal balance by regulating the fresh air supply, reduced surface runoff and thus modify the local microclimate through production of oxygen. They help in capturing carbon and reducing the level of smog, which are the reasons for rising temperatures. Air quality also improves with the deposition and less production of air pollutants through power plants. Proper selection of trees around the buildings provides benefits in both summer and winter season (McPherson, E. G., Simpson. J. R, 1999).

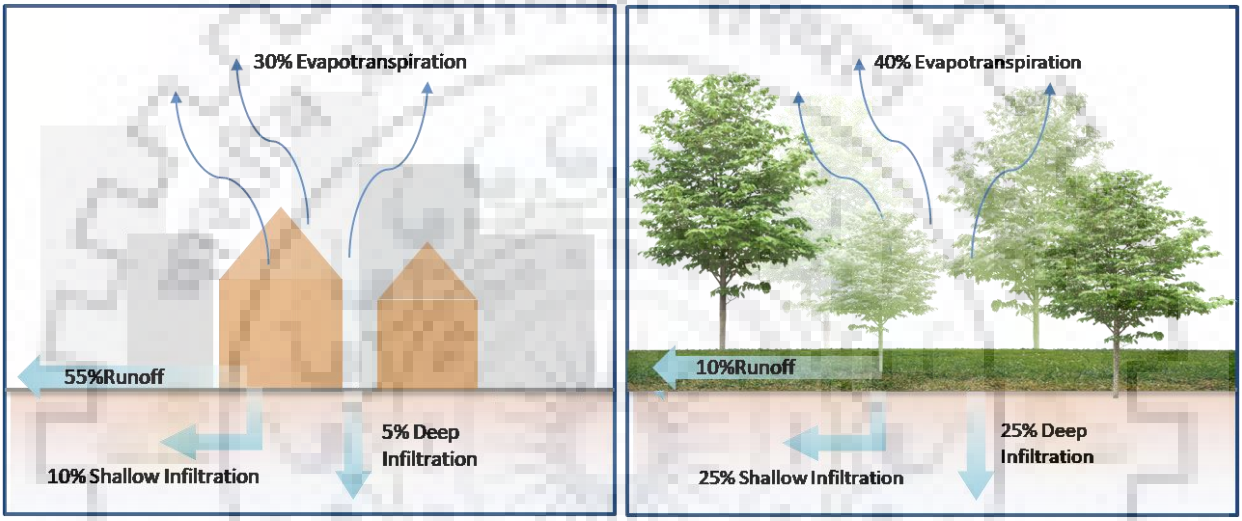


Figure 8 - Image showing change in rate of evapotranspiration between urbanscape and landscape

Trees and vegetation lower surface and air temperatures by providing shade and through evapotranspiration. Through the process of evaporation, energy gets transferred from the atmosphere and hence, links the energy balance of the hydrological cycle. Therefore if there is less amount of vegetation in the environment the remaining energy would be responsible for formation of extra heat which is responsible for the formation of UHI. Evapotranspiration process should be increased by promoting more vegetation and water bodies so that, they can replace sensible heat with latent heat. Increasing vegetation around buildings or to increase shade in the streets is the most effective strategy to control thermal balance. However, an overview of the energy balance and classification of the causes for the UHI will help in providing possible mechanisms for mitigation.

2.6 Summary

Literature Review helps in finding out the effect of UHI and its consequences and thus helps to understand the required mitigation process with the implementation of urban green space. It makes to understand the role of green spaces between urban infrastructure and how beneficial are they for providing benefits. Next chapter contains studies which are done for learning practical experiences of green spaces.

CHAPTER 3. Area of Interest

3.1 General

This chapter includes the two site studies conducted in Germany. One of the study site is Munich, which is the financial capital of Germany like Gurugram for India. The city being the financial and commercial hub with large number of the population is still maintaining quality of life with the implementation of green spaces by controlling the increase in temperature. Another study is from the city of Stuttgart which is also an industrial center of the country and is being considered one of the best examples for mitigating heat island management in the world.

3.2 Case of Munich, Germany

Munich is the capital of Germam state Bavaria and is one of the largest city in Germany after berlin and hamburg. Munich has nevertheless been able to preserve its special charm, not least because the predecessors have acted responsibly and with foresight. A key task of the administration is to retain Munich's unique atmosphere for future generations while at the same time, being open to change. (Chapman *et al.*, 2017).

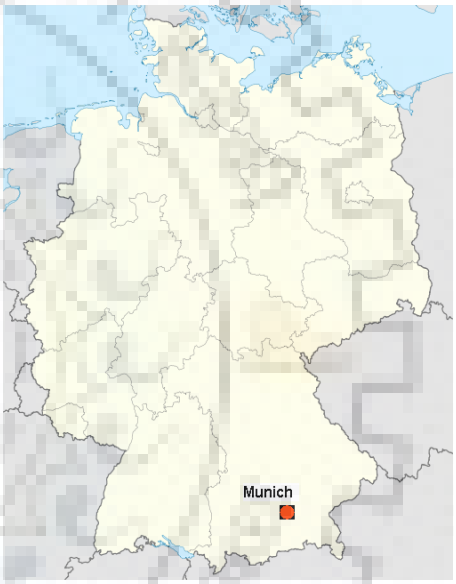


Figure 9 - Map showing location of Munich, Germany

3.2.1 City Profile

1. Geography

The city is situated in the southeast of Germany and spreads in an area of 310.4 km2 approximately. In 2011, the city has a population of 1.37 million. The city is situated at 520 m above sea level and located approximately 50 km far from the north of the northern edge of the Alps. Munich is settled and developed region even in terms of land cover and land use mainly since 2002.

2. Climate

The climate of the city is a humid continental type with warm summers. Mostly, the temperature within the city varies from -4°C in the month of January to 24°C in the month of July. The city gets annual precipitation of 967 mm. Climate of Munich also gets affected because of the sheltered position of the Alps. Alps effect the city in two ways – Proximity to the alps causes more rain and snow in comparison to other parts of Germany while on the other hand sometimes it result in flow of warm wind down the hill which can raise the temperature sharply in city.

3.2.2 Green Spaces in City

1. Administrative Approach

Munich is known for being a welcoming city. Munich is in good state because of economy, efficiency and prosperity. The city is booming and has potential to be in the future also. The city is attraction for art, advanced technologies, culture, innovation, education, business, and tourism in Germany and Europe and relish a excellence, living style, reaches first in Germany and fourth worldwide according to the Mercer survey 2015 and is considered an alpha-world city, according to the Globalization and World Rankings Research Institute 2015. (Chapman *et al.*, 2017).

Though Munich is already a developed city, therefore the major concern for city is now different. Their goal is to maintain quality of life by means that are both socially and ecologically sound and to find a balance between successful economic situation and high quality of life.

For achieving these goals, Munich has perspective Munich, Urban Development Plan, which was established by the city council in 1998 for the first time and since then has been updated several times.

i. Perspective Munich

For the first time in 2012, Munich City decided to publish the Perspective Munich report as a magazine. With the help of this magazine, the City Council wants to involve citizens in the development of the city. As according to city council "A key principle of Perspective Munich is the ongoing dialogue with the citizens." According to perspective Munich plan, there should be exchange of interests between public, so that they can implement the necessary changes which

are important in the eye of public. The major challenge is to develop a culture of openness & in depth dialogues with citizens and social groups.

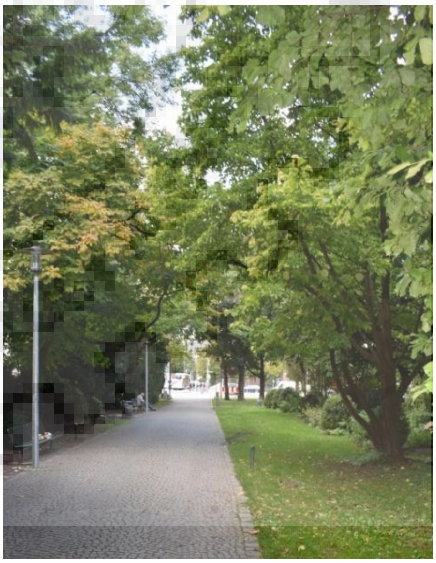
Perspective Munich has 8 guiding principles, 4 strategic guidelines, 16 thematic guidelines & 10 action areas for future oriented urban development. City administration took the responsibility for ensuring that all plans of action should be implemented in a way to maintain quality of life. These all strategies are prepared while keeping in mind that the city should be in balance. In order to maintain this balance all the strategies are revised time to time and being updated.

The developed city like Munich also has scope for improvement and in accordance with the guidelines it has to be done. There are several hot spots, selected in city for special consideration and has given special attention to look forward for more specific enhancement. After analyzing challenges, risk and potential of a space, area specific action and decision oriented concepts are made and implemented. The integrated approach of planning is the main feature of the plan. City Council in collaboration with urban planning and building regulation department develops the action plans.

2. Implementation Existed

a) Street Trees

Though very basic but most important for the cities. Wandering in the streets of Munich, one can hardly found any street/road that does not integrate trees, no matter whether it is highway, city roads or pathways. City council is highly focused for pedestrians and consider their movement as the first priority. Munich is a city full of public and highly attracted by tourists who loves to walk in & around, City council never fails to take care for their comfort and providing the best possible ways to have a nice time in walking around.



a

b

c

Figure 10 - Images showing aisle of trees in the city of Munich (a) Pathways (b) Highways (c) City Roads

b) Public Spaces

Munich has a fastidious city life, thus has well managed public spaces. The spaces in city are well equipped with all facilities, but the most fascinating factor is shaded seating spaces, designed in a way so that one can spend a pleasant amount of time there. The use of green implementations in the spaces is a good approach to provide relaxation.

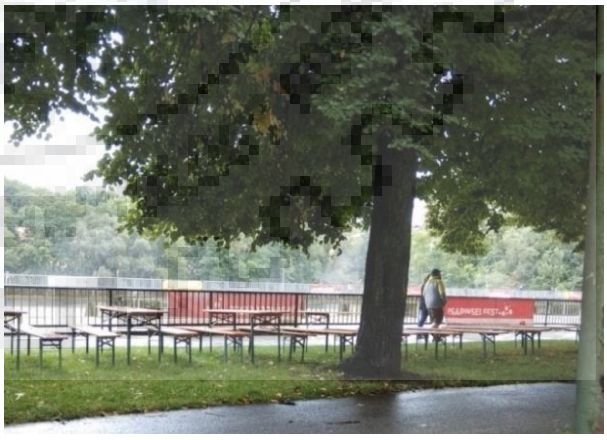


Figure 11 - Images showing seating spaces at public places

Public places are open and always accessible for everyone. Public place shapes the community ties and encourage residents to live together. Public places are not only spaces they are the environment created for increasing the quality of life in a region. These spaces are used as an effective way to exchange words and to enjoy time together with your loved ones. Not only for communication and enjoyment, these spaces have also proven to have a good effect on human health and livelihood. These spaces always depict the culture and social value of the place. It indicated that the more lively and dense the public space is, the more happy and democratic the society is.

c) Landscape

The best part of the city is that it does not have any unplanned space. At all places wherever there is open or vacant land available, City especially take care those areas to properly landscaped them. The Landscape in the city helps in maintaining air quality levels at some extent and works as a buffer zone for the city.

Figure 12 - Images showing landscape planned in city

d) Green Facade

Though it's very rare to find green walls in the city, but still there are some places where it has been implemented and has been receiving a great amount of appreciation from users, as they are beneficial in providing thermal comfort of the place but it definitely requires high amount of attention for the maintenance.

Figure 13 - Image showing green facade

e) Public Park

If it comes about Munich, then it's not at all possible to forget the name of the Englischer Garten. Englisher Garten is the largest public park in Europe. The visit to the Englischer Garten gives the feel of green world which is free from the concrete world existing outside. The Park is so huge and have a sufficient space to hold all types of public activities like cycle tracks, playgrounds and also have a space for activities like tea ceremonies (where Japanese tea ceremonies regularly takes place). Park also has beer gardens, one of the most visiting place there, for which the city is known for.

Figure 14 - Images showing Englischer Garten

f) Water Bodies

Munich is well planned with a network of the Isar river. Floating water bodies like fountains at public places, in gardens etc. are good for encouraging the air exchange and thus, maintains temperature to increase upto some extent only hence, proves helpful in maintaining comfort level.

Figure 15 - Images showing various water bodies in city

3.3 Case of Stuttgart, Germany

Stuttgart is the capital of the German state Baden-Wurtemberg. The city is known for the high tech industries and is located in the central of the industrial region of Germany and therefore known as the “Cradle of the Automobile” There are various other names given to the city as Stuttgart is also known as the "Stuttgart Cauldron" because of the generation of heat in a valley. Stuttgart has been planned to respect and protect nature. Over 60% of area of the city is green and is considered as one of the greenest metropolitan city.

Figure 16 - Map showing location of Stuttgart, Germany

3.3.1 City Profile

1. Geography

Stuttgart is situated in the southwest of Germany and spreads in an area of 207.4 km2. Being situated in the valley the location of the city influence it’s local climate. The city is located in the basin formed by the Nekar river and surrounded by steep hill slopes. The city is situated at 240 m above sea level while the surrounding hills around the city reaches up to 500m above sea level.

2. Climate

The climate of the city is mild, temperate type with sometimes happens to be extreme. The temperature in the city varies from -1°C in the month of January to 26°C in the month of July. The city gets annual precipitation of 869 mm. The average temperature in the city supports the vine production in the city. Wind speed in the city is generally low, and hence, affect air quality and also becomes one of the causes of UHI. The city climate gets affected by the surrounding hills as the city being in valley feels warmer as compared to the hilly region nearby.

3.3.2 Green Spaces in City

1. Administrative Approach

The city develops its first climate atlas in 1992 in Stuttgart, which illustrates how urban development is affecting the flow of air in the city. It also identifies surrounding hills, forest areas, agricultural land and other green spaces as a source for the flow of fresh air in the city. It was noticed that because of the increase in building upon hills, the flow of fresh air in the city gets interrupted as built up area replaces vineyard on the hills which were once promotes fresh air supply to the city center.

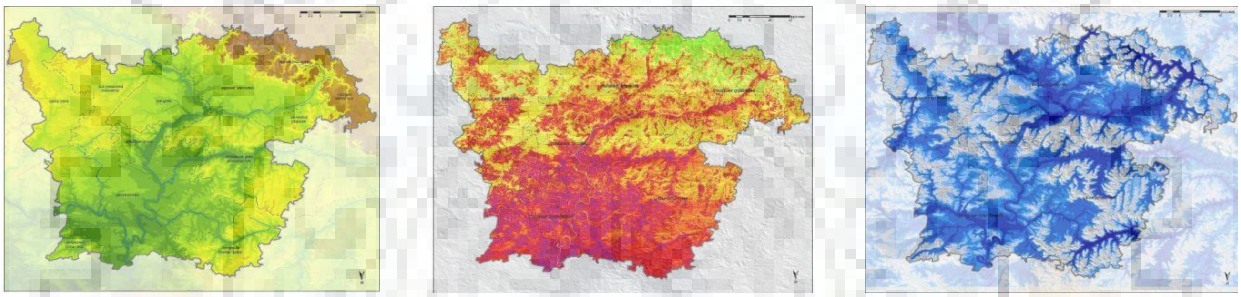


Figure 17 - Maps from Climate Atlas of the City
Source - Verband Region Stuttgart (2008) Klimaatlas Region Stuttgart.

Since 1938, City of Stuttgart recognized the importance of climatic conditions for the benefit of humanity. The city has employed a meteorologist especially to examine and analyze the climatic situation in the city to understand the link between the urban development and climate. In accordance with the topography of the city, Climate Atlas was developed in Stuttgart which includes the maps for distribution of air flow and temperature. Environmental office was established in the city to complete the task of assessment of developments and how these developments are affecting the local climate so that the problem of the city can be solved.

The preservation of the natural environment in urban areas is principally guided by the Act of Federal Nature Conservation. This Act restricts any changes in preserved green spaces and also restricts any change in the land use of those spaces. The regulation in the city was revised in 2004, and includes actions for the urban development like maintenance of social needs, fulfilling of economic and ecological demands and thus moving towards sustainable development.

Plans for urban development were made in a way that they would be essential for the establishment of a better environment and will help in the protection of natural resources. Development should proceed in a way that will be helpful for preserving the urban pattern and landscape of the cities.

In 2008, City has published new Climate Atlas, which have the standardized climatic data listed out for the whole area. In 2008, the Climate Booklet of Urban Development was revised which was first published in 1977. This booklet is based on the Climate Atlas of the city and includes the description of the local climate of the city and also mention from where the local air exchange can happen in the city.

The Booklet defines the aim which should be achieved at the national and Local level to resolve the problem related to local climate. Some of the aims are following:

Preservation and Acquisition of Green Space

Landscape and Open-Space Control Plan

Green Spaces & Green Corridors

Roof Greening and Facade Greening,

Securing the local air exchange (Boone, 2012)

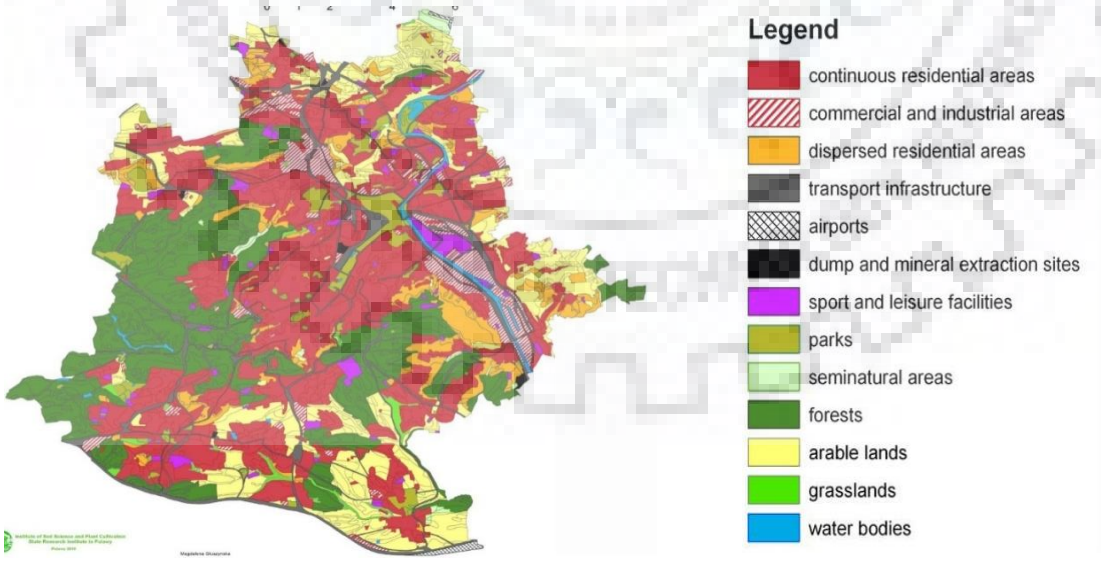


Figure 18 - Landuse Map of Stuttgart according to Climate Atlas of the city
Source - Verband Region Stuttgart (2008) Klimaatlas Region Stuttgart.

2. Implementation Existed

To achieve the goals, green interventions are implemented at locations having an important role in the provision of air movement and for the development and protection of open spaces and also to encourage more vegetation in the city. In consequences, Stuttgart follows the strategy to be the green and thus to achieve a high level of livability.

a) Urban Park

Stuttgart has connected the small green pockets into large green 'U', due to which it is now possible to go all the way from central garden. Now the city has a large green public park in the shape of 'U' named Rosenstein Park. This huge park proves out to be helpful in making city cooler.

Figure 19 - Image showing Rosenstein Park
Source - Juergen Baumueller

b) Green Corridors

With the use of ventilation and green corridors, Stuttgart has protected the city from the warm winds. This also helps in fresh supply of air in the city and makes the city enable to develop resilience against global warming. Thus, the city proves out itself that it can fight with the effect of UHI. Ventilation corridors have been kept wide and open with trees on both the side which helps to sweep out the clean air from the city.

Figure 20 - Image showing ventilation corridors in the city

c) Green Roof

In Stuttgart green roofs are playing substantial role mainly because of the location of the city in the valley. As the flow of air from surrounding hills encourages the movement of air at the upper level (top of the buildings) and because of that green roofs are working on making the city cool. The government provides subsidies for construction of green roofs to local citizens.

Figure 21- Image showing green roof
Source - Photograph by Diane Cook and Len Jenshel

d) Cool Buildings

The city is the ruler in the concept of using cool materials for buildings. Most of the facades in the city are made up of those materials that have high albedo value. One of the famous examples in the city is The City Library.

Figure 22 - Image showing Stuttgart's city library

e) Urban Water

Stuttgart has numbers of fountains and lakes in the city. Water applications, mostly work when the water is in movement as in a fountain. Use of water bodies in the city in the form of fountains and cascades are more effective than lakes.

Figure 23- Image showing fountain in Rosenstein Park, Stuttgart, Germany

3.4 Lessons Learnt

1. Munich

The goals formulated for the entire city are put in concrete terms in the action areas and are provided with appropriate implementation strategies. Work has been divided between specific specialized department. Along with the administration, other officials of the city are also engaged in work in making the city more livable and green.

Education and upbringing to keep the city image and to create more breathing spaces is the important part. Munich attaches importance to quality in urban construction, whether in its city center or at the outskirts. The more housing complexes are built, the more important it becomes to create sufficient green areas and other open spaces. Attractive green areas are having numerous possibilities with them.

2. Stuttgart

With the help of Climate Atlas Map and planned development Stuttgart has banned construction in the surrounding hills on the sites which are obstructing air exchange in the city. The green intervention in the city is always encouraged by local regulations. That's why the city became able to achieve the desired result.

Stuttgart does not allow any type of development which can obstruct the flow of air in the city. Solutions like green roof, green façade is promoted in the city to encourage the fresh air flow in the city. The city takes special care in the protection of already existed green spaces and have strict laws, if one wants to remove any type of vegetation from any place.

For example, Stuttgart protects all trees growing in the urban core with a trunk circumference of more than 80 cm in height of 1m with a tree preservation order. (Rehan, 2016)

Vegetation in the nearby areas or at the border of developments also influences air exchange and exert positive effects on the microclimate of the place. More larger and connected green spaces help in maintaining air hygiene of a place and makes environment of the place breathable.

The planning of the city has done not only to protect nature, but also to encourage the natural patterns of the wind flow, due to which the city is the ability to cope up with the effect of UHI.

The city also enhances the amount of dense vegetation in the form of larger connected green spaces & also provides large opportunities for maintaining the city life better. Hence the climate planning strategy of the city is considered as one of the best examples of heat island management in the world.

3.5 Summary

These studies shows that how favourable are the green spaces in providing quality of life and mitigating the effect of increased temperature and thus proves out to be valuable for learning advantageous lessons. Next chapter will discuss about the study area selected.

CHAPTER 4. Study Area, Gurugram, India

4.1 General

This chapter involves discussion about the study area. Gurugram, the city in the National Capital Region of India, which has become the topic of discussion among various as it stands as the living embodiment of the ongoing growth and development of the country and has been known as the 'Millennium City' of India.

4.2 City Profile

Gurugram is in Indian state Haryana and is part of the National Capital Region of India. In the country, Gurugram is on the third highest position for income per capita. The city today has become one of the leading industrial and financial hub in the country. The city offers world class corporate hubs, new commercial offices, BPO Companies and so on, which makes city stands out in terms of business and industries.

Figure 24 - Map of India showing location of Gurugram

4.2.1 Geography

The city is situated in the northern part of the country at 28.47°N and 77.03°E and lies in the southeastern part of the state. The city is situated at 217 m above sea level. Gurugram is located on NH8 (National Highway 8), very close to the Indira Gandhi International Airport. The city is situated just 32 kms in the southwest of New Delhi. According to the 2011 census, the city has a population of approximately 8 million.

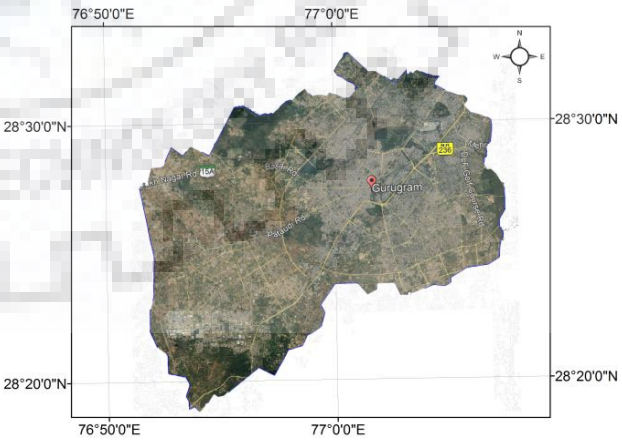


Figure 25 - City Profile map showing coordinates

4.2.2 Climate

The climate of the city exists between subtropical humid and semi arid. Mostly, the temperature within the city varies from 3°C in the month of January to 40°C in the month of June. The city gets annual precipitation of 714 mm. Winters in the city are cold and foggy while summers being very hot. The prominent wind in the city is southwesterly.

4.3 Growth Dynamics of Gurugram

Gurgaon has been a 'Gaon' that is the village without any recognition or identity before 1970. With time it first evolved as a small town. Gurgaon district has witnessed a phenomenal growth in all spheres of developments, particularly in industry and urbanization.

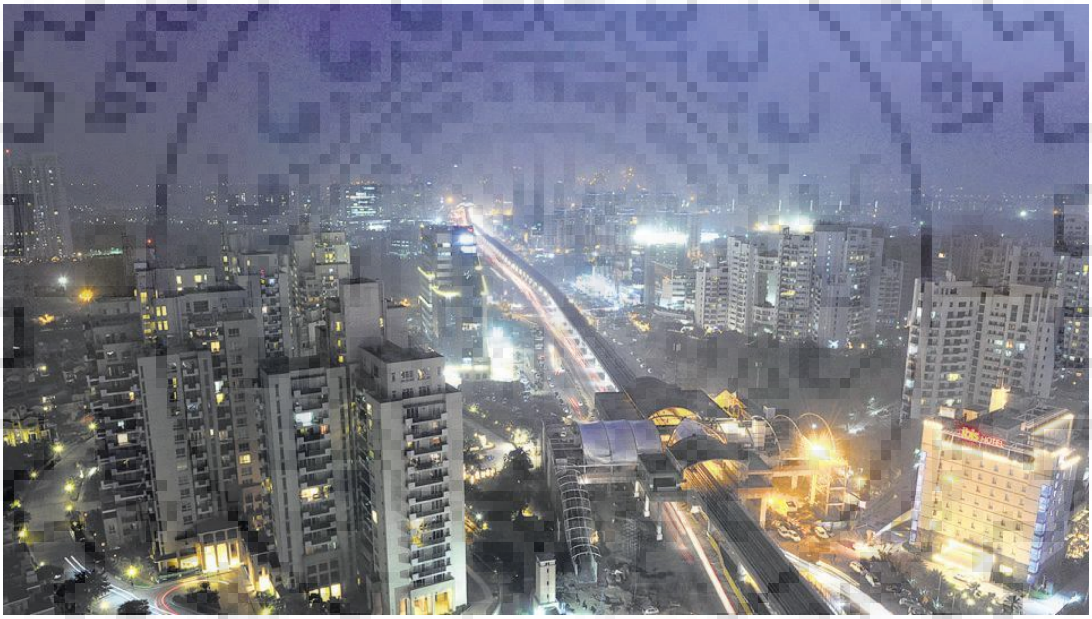


Figure 26 - Skyline of the City Gurugram

The coming up with an idea of establishing Maruti Suzuki India Limited plant in Gurgaon in the 1970s was the known as the turning point for Gurugram's economy and with the development of the plant in 1983, growth of the city starts increasing at a very faster speed than ever. Growth in the city was mainly influenced by the interest of private developers.

UN World Population 2007 has recognized that globalization is the factor which is mostly responsible for the city growth as it says "The impact of globalization on city growth patterns

marks a critical difference between past and present transitions. Cities are the main beneficiaries of globalization, the progressive integration of the world's economies. People follow jobs, which follow investment and economic activities". This statement correctly fits for the city of Gurugram. In the city job center has started developing from the end of 1990s, after that, people started moving into the city and this makes private real investors to show more interest in the city and thus started growth of Gurugram. During the initial years, construction started at a, slow pace, but from the end of 1990s, the city experienced real growth both in terms of population and spatial area.

The economic value of the city starts rising because of the generation of jobs in the service as well as in the industrial sector, due to which people start migrating in larger scale from other states in the city. One of the major force to make the city as corporate capital is public – private partnership model. The other reason is the close proximity to the capital city New Delhi, which makes easy access to the administrative hub of the country. The city has good connection routes which enable the human to increase business

The two cities came up within the Millennium City that are the Old Gurugram and New Gurugram, which stand on either side of the NH 8.

The Old Gurugram constitutes the core town and is being managed by the Municipal Corporation of Gurugram since 2008 and till 2008 it was under Municipal Council. While on the other hand the space of New Gurgaon, with plush buildings and commercial offices where everything is managed by the private developers.

Presently, the New Gurgaon has been under the Municipal Corporation since 2008 for the areas outside the complex and inside their mini worlds it is the private developers. Prior to 2008 it was under none administrative body and the inside of their mini beautiful islands was managed by the private developers giving them a comfortable life in lieu of the maintenance charge.

The private developers always been involved in the development of Gurugram. They can directly acquire land from the people without the involvement of Government, which makes the inappropriate scale of development in the city. On the unitary hand, this favor of government proves in emerging the city as an economical hub while on the other hand it increases unplanned growth of infrastructure and makes city moving far away from nature.

4.3.1 Demographic Change

The demographic turn includes the sharp increase in the population numbers. The metropolis have developed leaps mainly because of an increase in industrial sector in and around gurugram. Gurugram has evolved as a city in a series of changes. The high rate of growth of population in the city during 2001 and 2011 has caused high migration from neighbouring states. This mainly happens because of the large availability of jobs and work opportunities in the city.

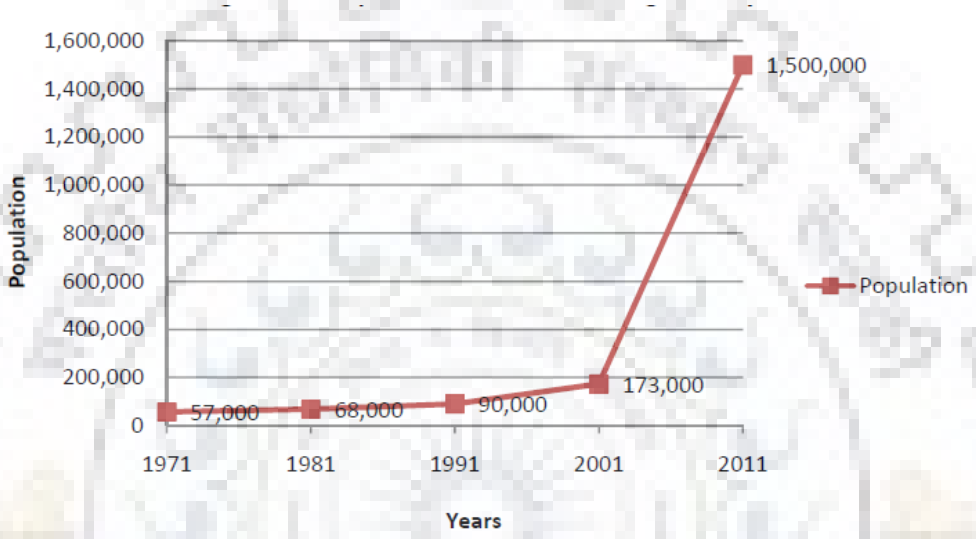


Figure 27 - Population growth of Gurgaon City
Source – Census 2001 and Census Provisional 2011

4.3.2 Socio-Cultural Change

The increase in the population of the city is not only in numeric spurt, but also experienced change socio-cultural practice. The population in the city has become more heterogeneous. The culture of the city has changed and forms a home for diverse cultural groups.

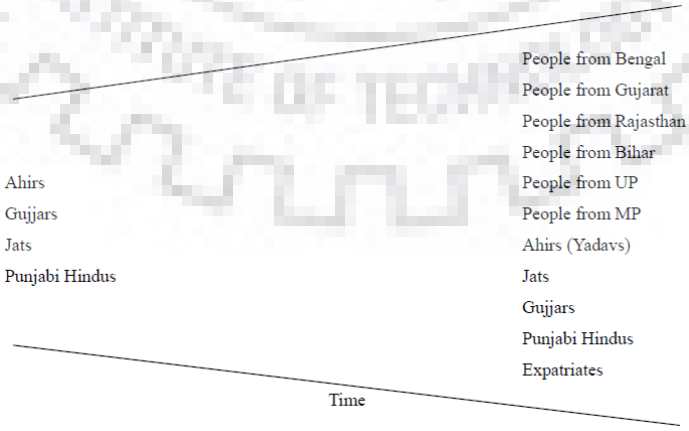


Figure 28 - Socio Cultural change in city
Source - Imperial Gazetteer of India, vol. 12, field work during 2009-2010.

4.3.3 Spatial Area Change

With the change in the demographics of the city, the spatial area of the city also gets changed. As there is a sharp rise in population of the city within the last 10 to 20 years, there has been changed in the land use, land cover of the city.

The small town of Gurugram expanded over and accumulate all the surrounding villages within which were initially not the part of the city. The area of the city has increased rapidly, which transformed the lands of the city as takes over most of the agricultural land got converted into residential land.

Temporal Analysis has been done for the years of 1991, 2001, 2011 and 2017 with the help of Landsat data to find out the amount of spatial area change in the city. The need of building houses for more people has changed to build up area of the city. The increase in areal extent of the city brought a serious change in the landscape of the city. Following maps of the year 1991, 2001, 2011 and 2017 shows the changes in land use land cover of the city.

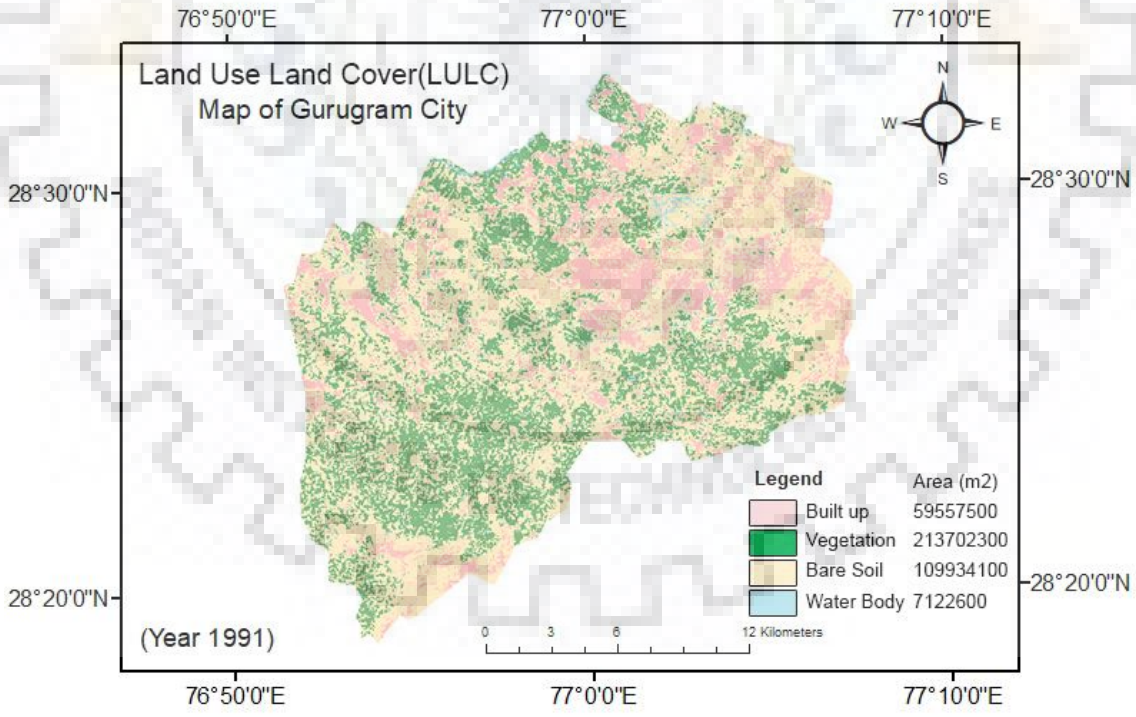


Figure 29 - LULC Map of Gurugram of the Year 1991

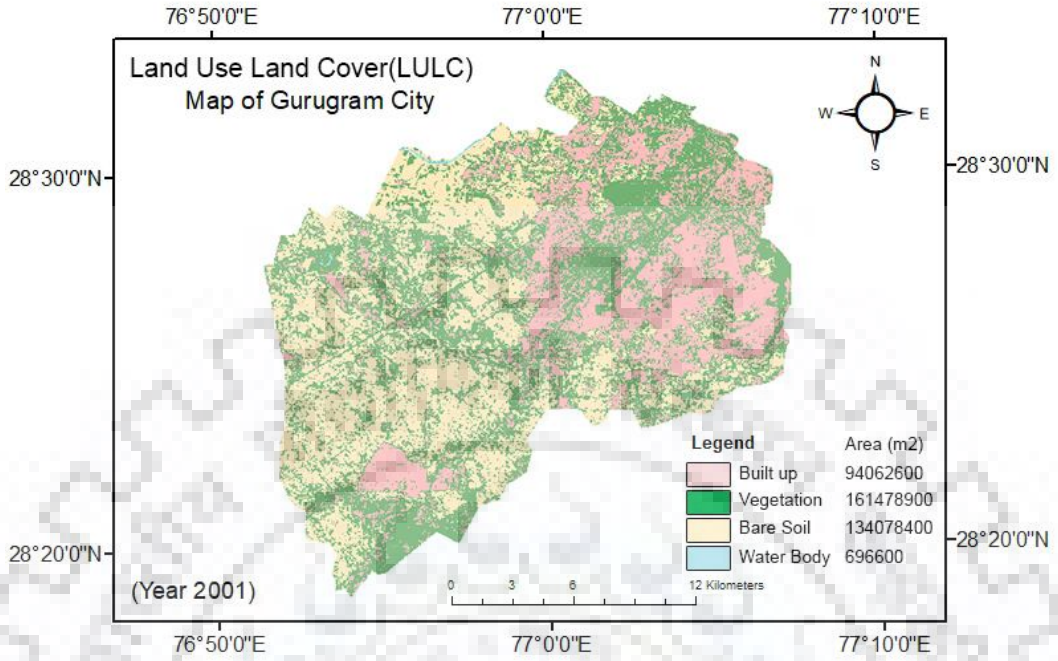


Figure 30 - LULC Map of Gurugram of the Year 2001

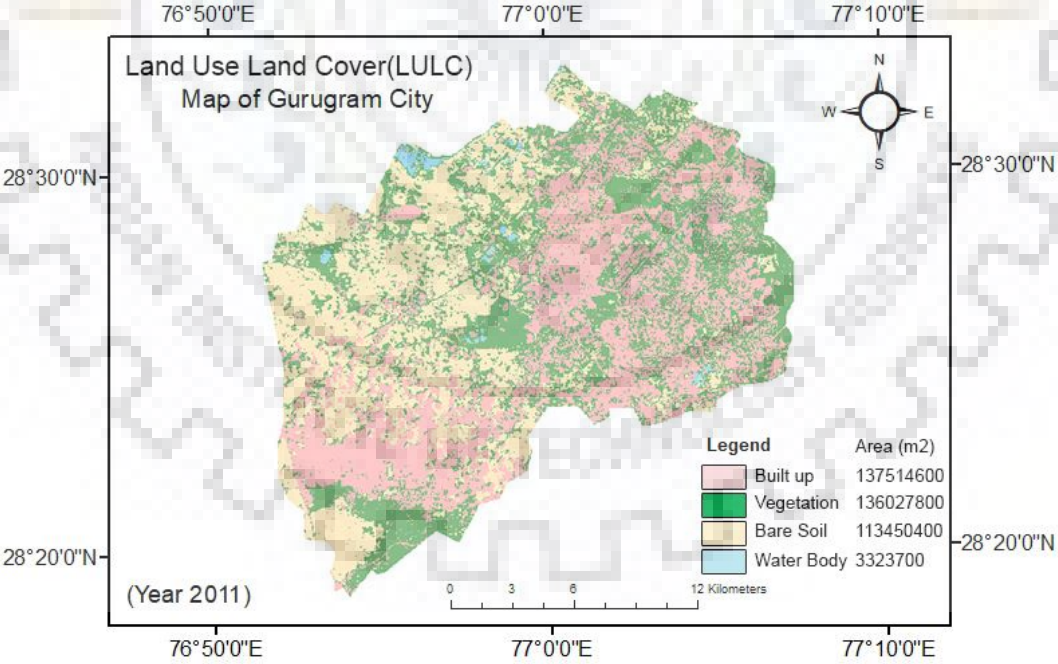


Figure 31 - LULC Map of Gurugram of the Year 2011

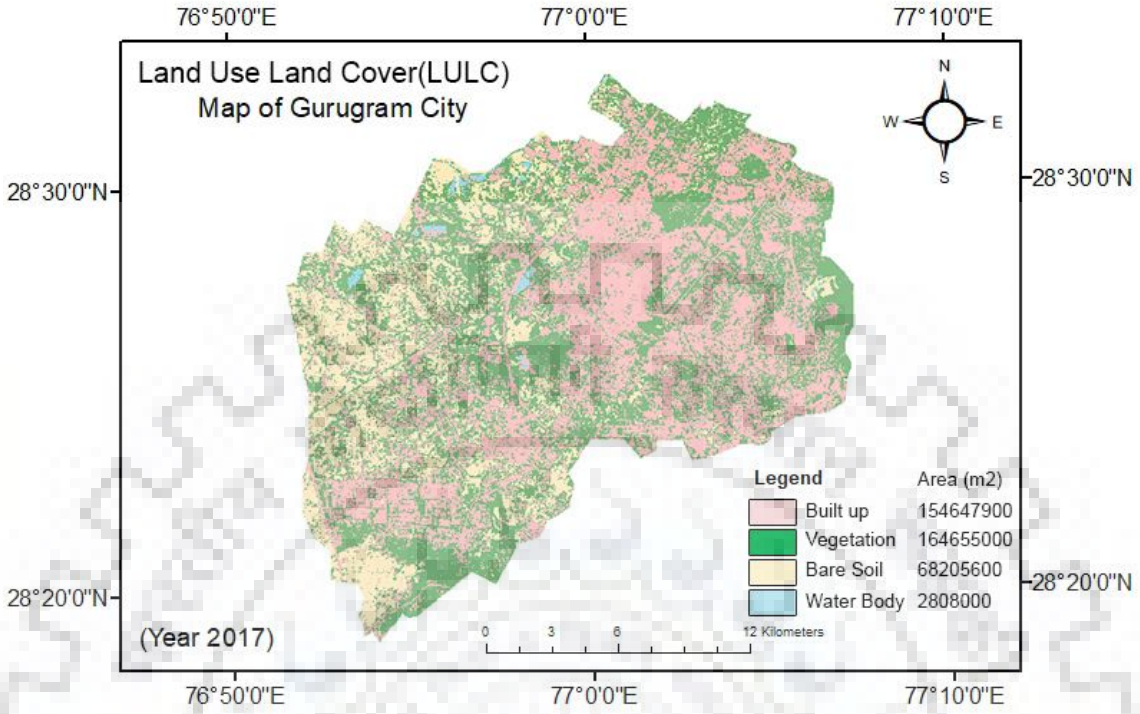


Figure 32 - LULC Map of Gurugram of the year 2017

Type	1991	2001	2011	2017
Built-up	59557500	94062600	137514600	154647900
Vegetation	213702300	161478900	136027800	164655000
Bare Soil	109934100	134078400	113450400	68205600
Water Body	7122600	696600	3323700	2808000

Table 2- Sowing changes in spatial area (m2) from 1991 to 2017

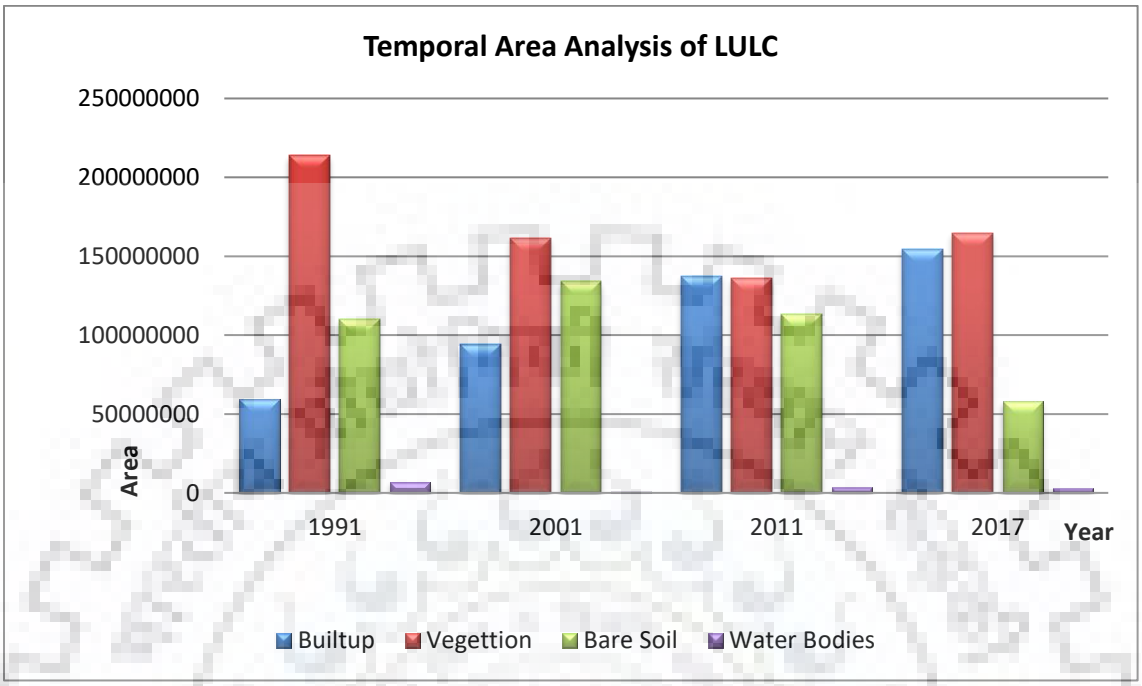


Figure 33 - Showing change in area pattern over course of time

4.4 Present and Upcoming Challenges

This drastic change in the population graph of the city has brought a cultural turn and renders the city with new urban personality. The today's urban personality of Gurugram along with providing great infrastructure and services to the users also opens a path for upcoming challenges which if not taken care can cause a severe problem as they are causing now.

Increase in population has given rise to numerous problems like increase in the number of vehicles which became the reason for increased amount of air pollution. The other problem is that unplanned growth in the city has taken a fast pace, and increasing the amount of concrete structures in the city, leaving behind the very least amount of vegetated area. Less amount of green spaces and also the unavailability of water bodies in the city are affecting the natural environment and thus becoming the reason for disturbing the energy balance in the city.

Sudden growth left the city with major challenges, such as there are a number of patches in the city which are left out as it is and are reasons for an increase in the amount of dust particles and also for increasing surface temperature in the city. Use of low albedo material in builtup

structures is almost everywhere in the city, one of the major reasons for increasing multiple absorption and thus affecting the thermal balance of the city.

4.5 Summary

The study about the city finds out about the challenges the city is facing. The growth of the city, mainly in the last 20-30 years results in evolution of Millenium City. The City has experienced both the demographic and areal dynamics at a fast pace recently. Both demographic and a real spurt has occurred simultaneously. This dynamic has led to a change of the cityscape.

CHAPTER 5. Problem Identification

5.1 General

This chapter incorporates the analysis of meteorological variables and land surface temperature maps for the study area. The analysis has been done to identify the problem in the city that how much change in variables are coming over the years and which region mainly suffers because of an increase in temperature over due course of time.

5.2 Analytical Framework

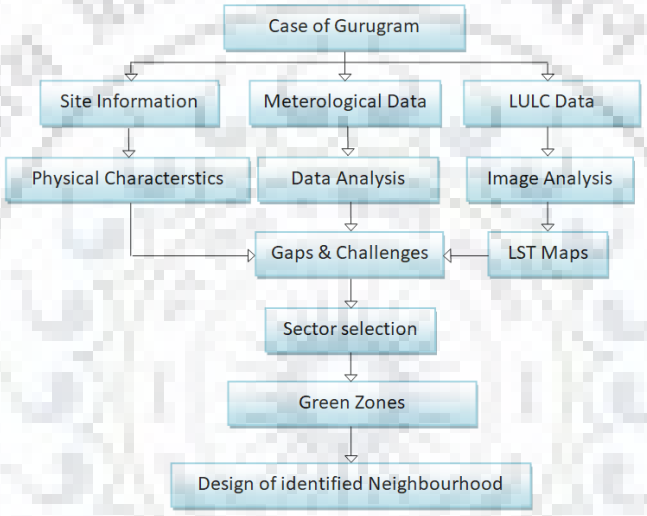


Figure 34 - Flowchart of Framework

5.3 Analysis of Meteorological Variables

Meteorological variables like temperature, humidity and wind data shows and depicts the weather of the place and if taken an average of 30 years it shows the climate of the place.

5.3.1 Weather Stations Data

The climate data for the Gurugram city has been calculated for noticing the change in variables. The data of two nearby weather stations have been recorded. An average of two weather stations has been taken to analyze the data for the year 1991, 2001, 2011 and 2014.

The graph was generated on a monthly basis for each year to notice the change in variables. Following are the graph generated for temperature, precipitation and wind speed.

5.3.3.1 Year 1991

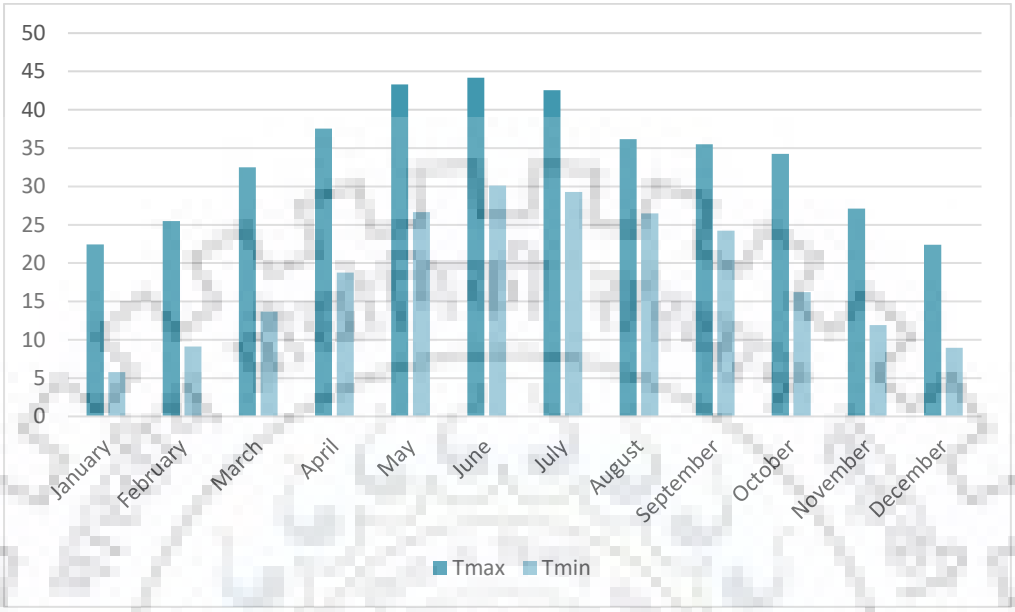


Figure 35 -Showing min & max temperature

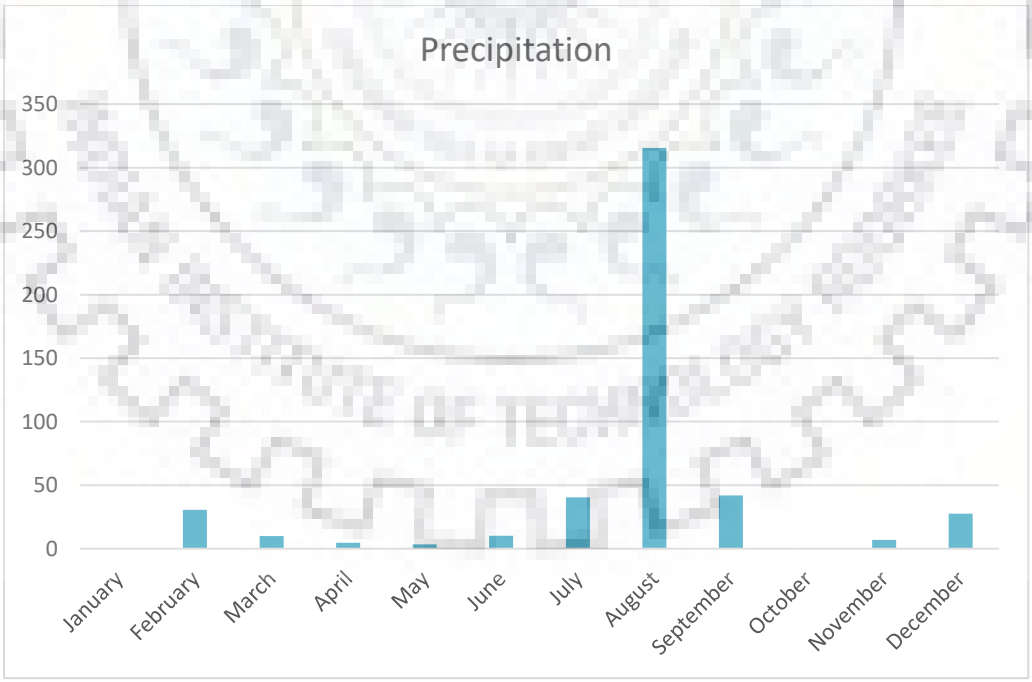


Figure 36 - Showing amount of precipitation

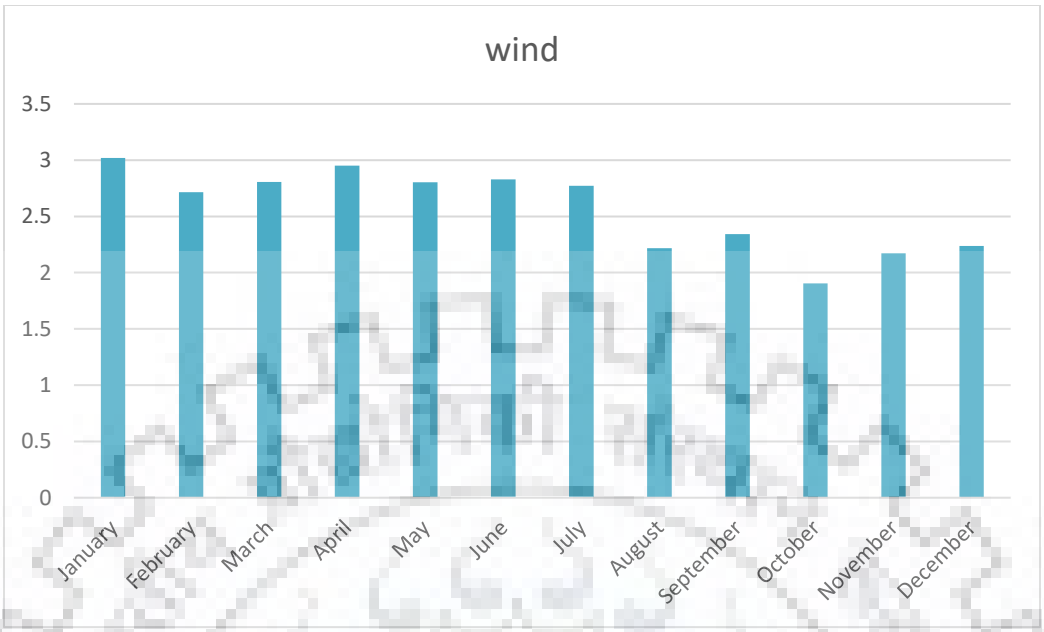


Figure 37 - Showing wind speed

5.3.3.2 Year 2001

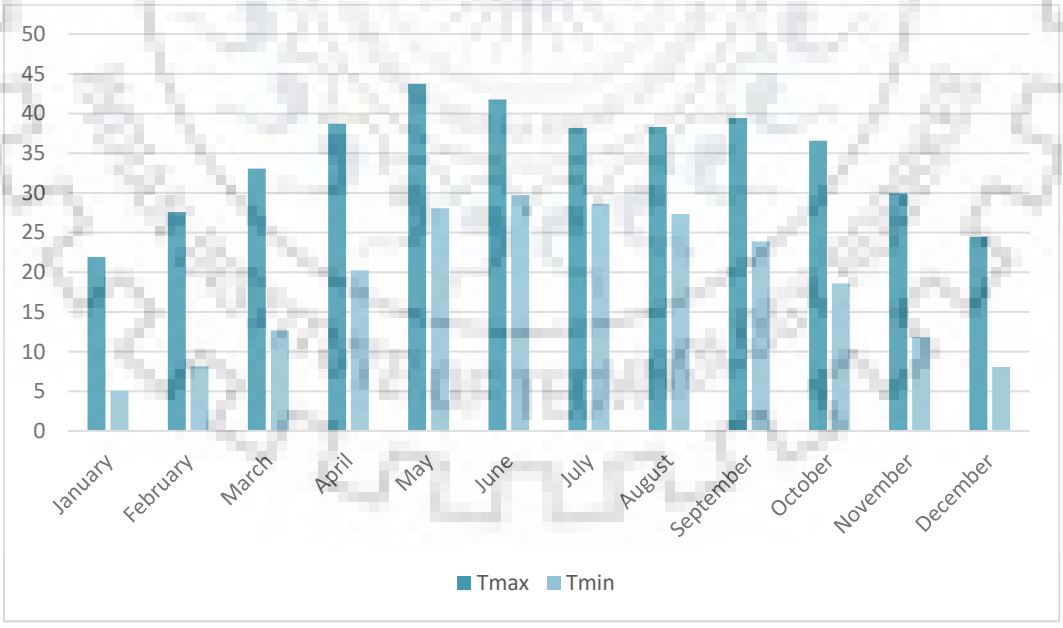


Figure 38 - Showing min & max temperature

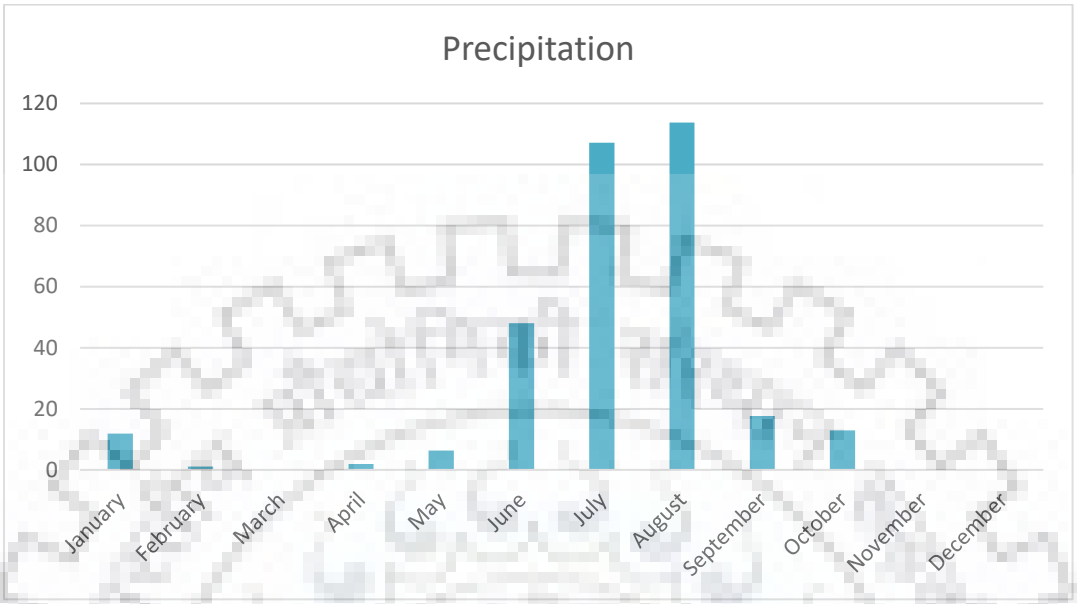


Figure 39 - Showing amount of precipitation

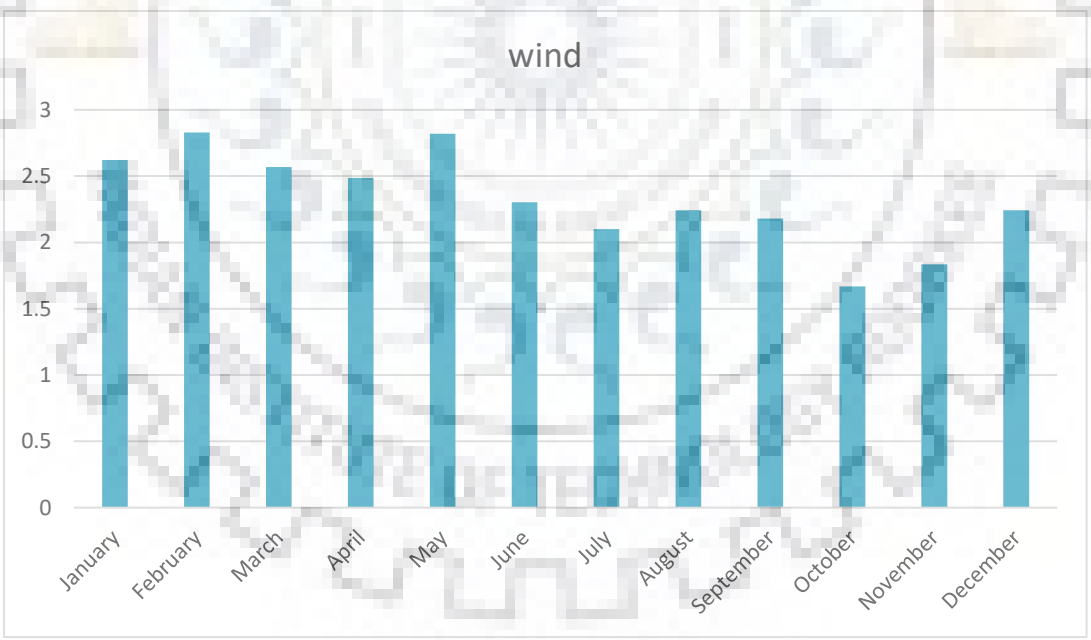


Figure 40 - Showing wind speed

5.3.3.3 Year 2011

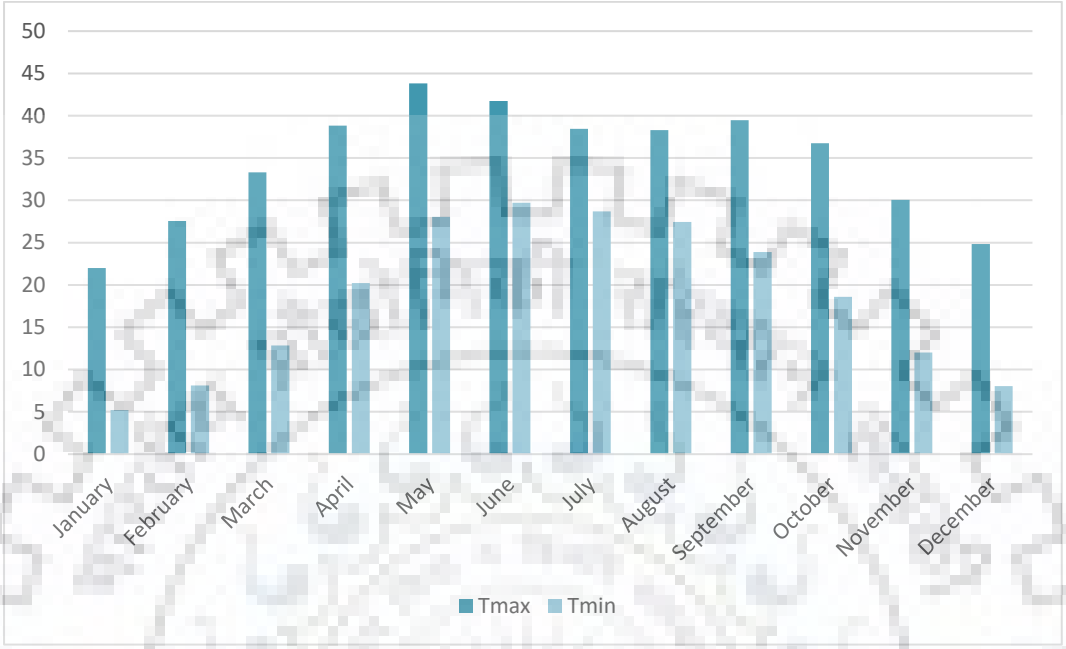


Figure 41 - Showing min & max temperature

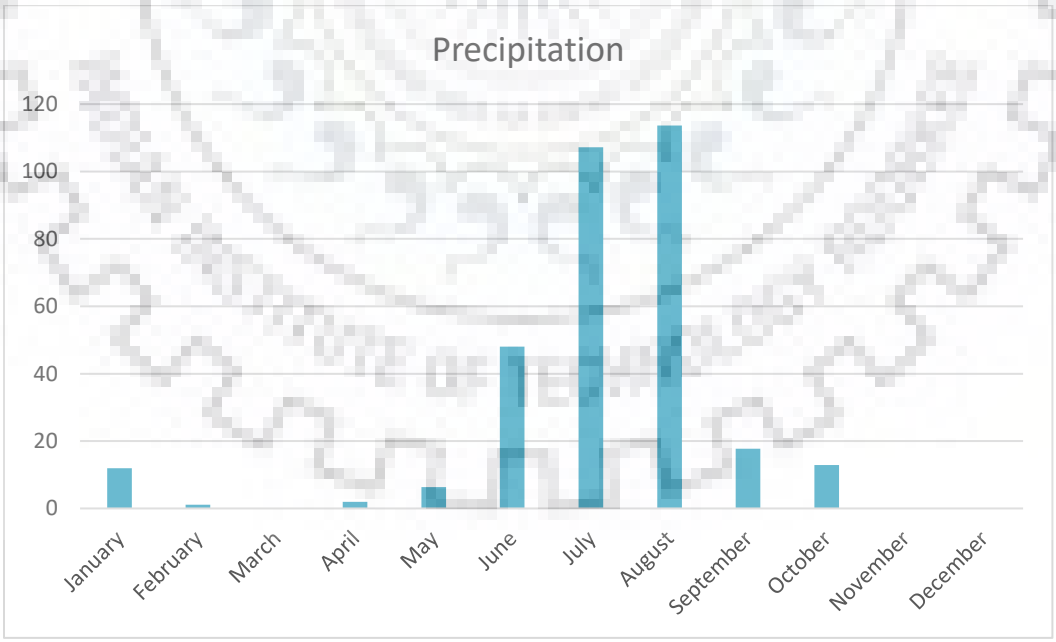


Figure 42 - Showing amount of precipitation

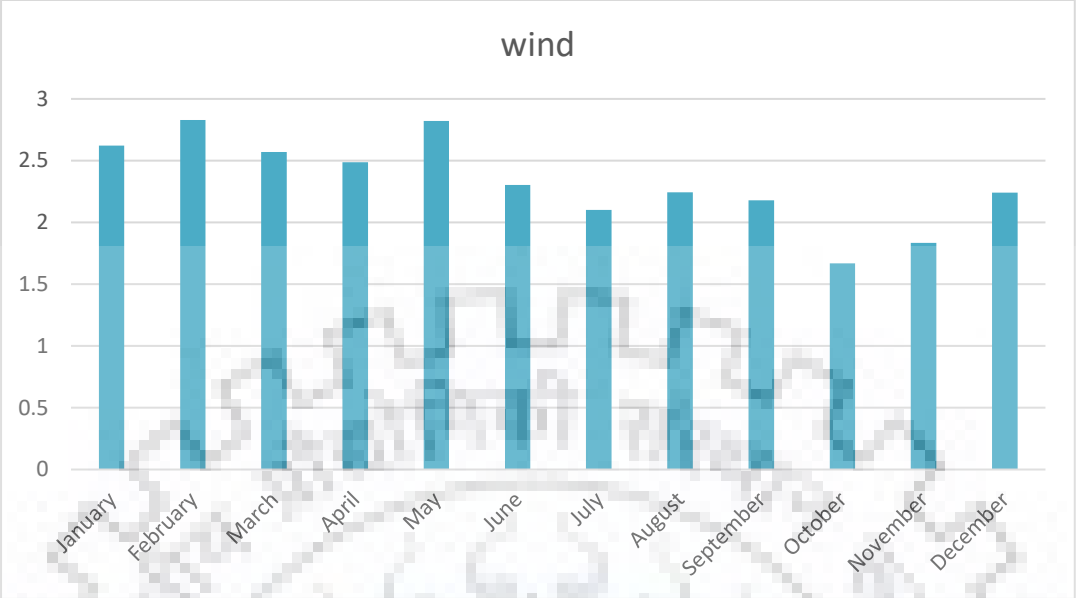


Figure 43- Showing wind speed

5.3.3.4 Year 2014

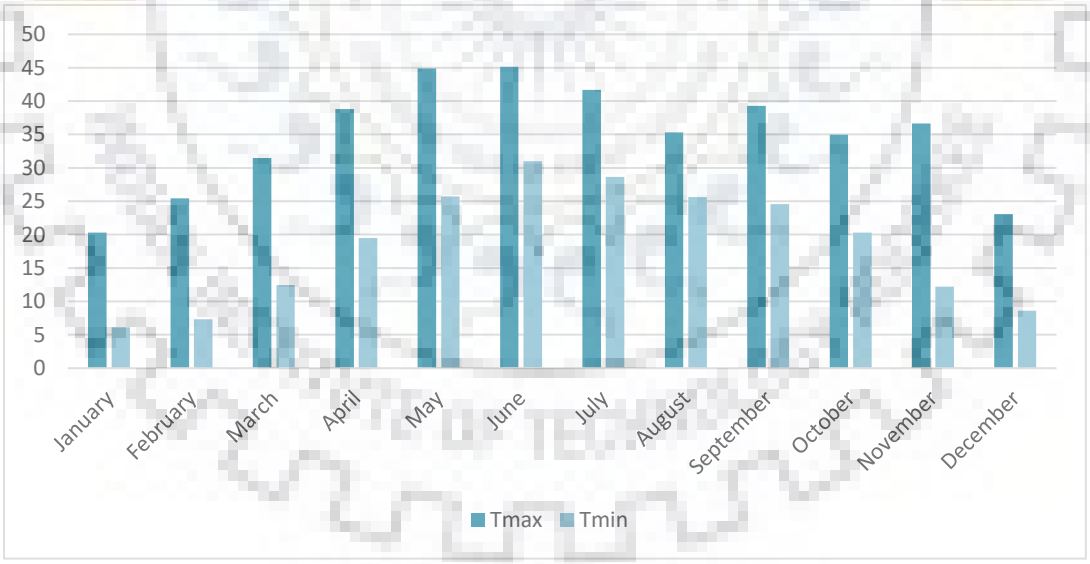


Figure 44 - Showing min & max temperature

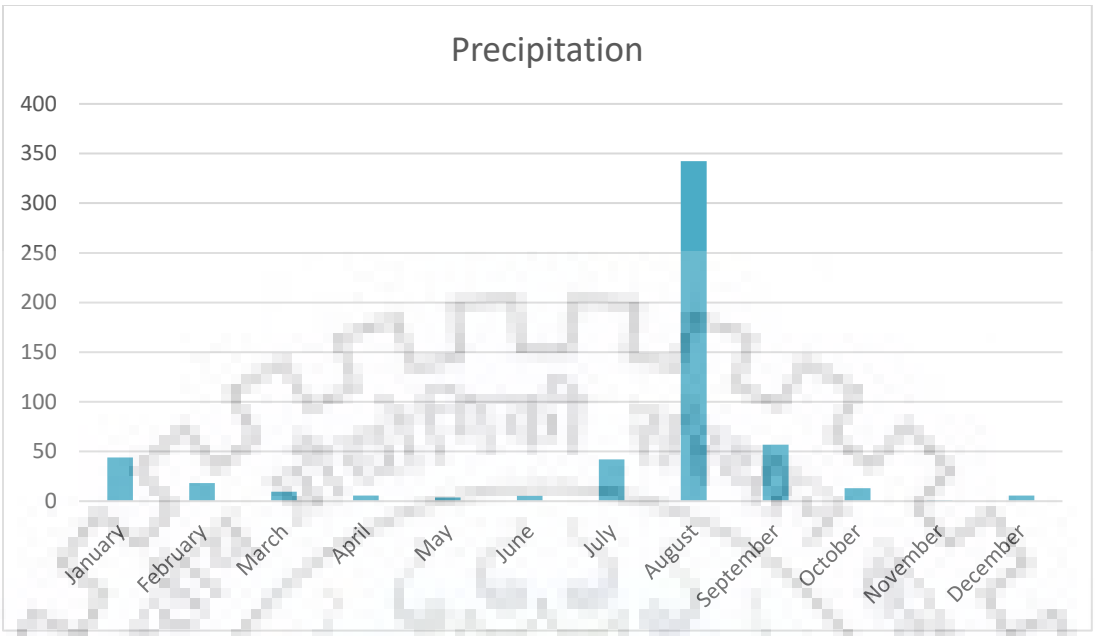


Figure 45 - Showing amount of precipitation

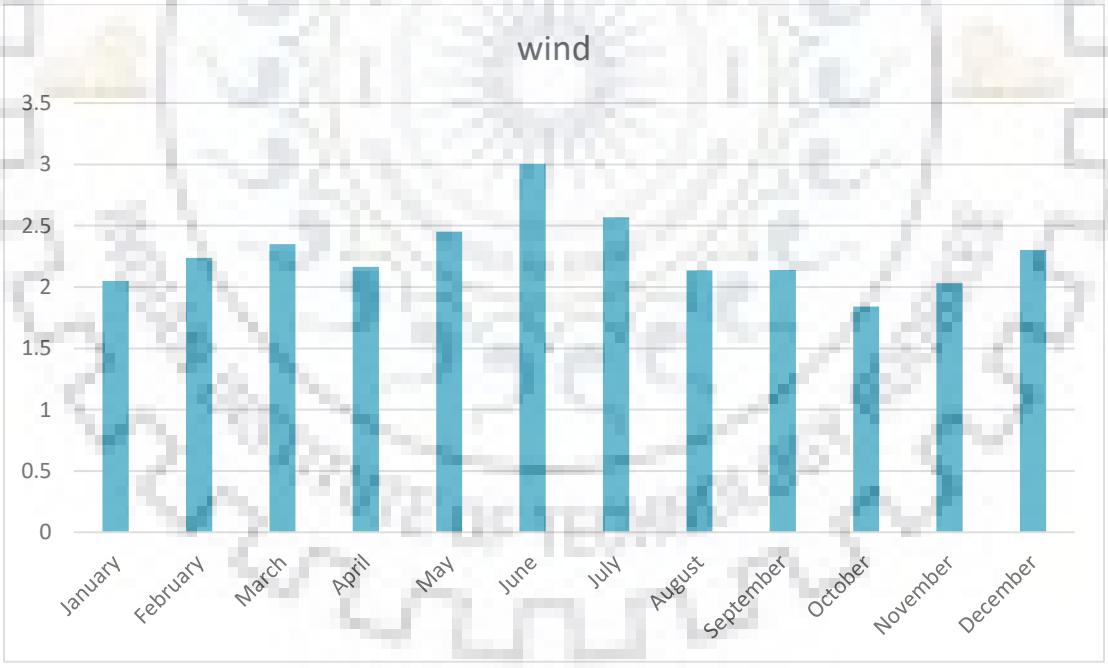


Figure 46 - Showing wind speed

The result of the each year has been analyzed and compared and change in the value of the temperature is visible. In the year 2014, the maximum value of temperature crossed 45°C and is increased in comparison to other years. Figure 47 shows the minimum and maximum temperature curve for each year. The thicker line shows the maximum temperature and the thin line is showing the minimum temperature for the particular year.

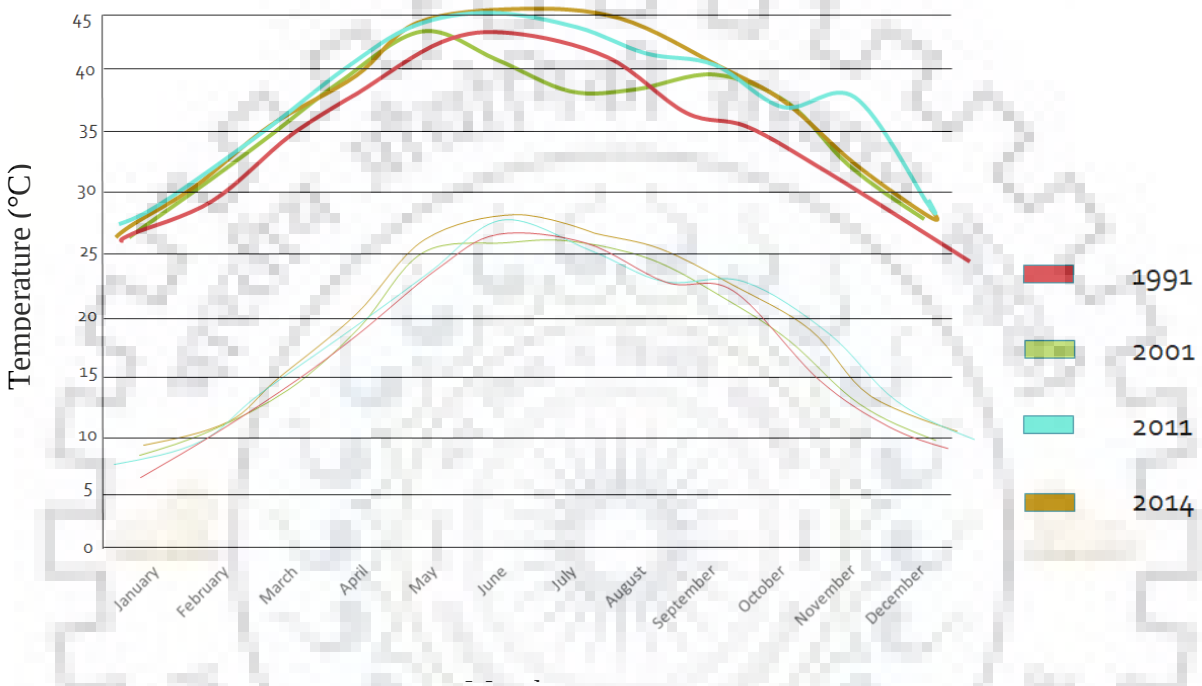


Figure 47 - Showing average temperature value of the above studied years

5.3.2 Land Surface Temperature

It has been analyzed that the temperature value in the city is continuously increasing. But now the question arises in which part of the city major differences are coming. To analyze this situation land surface temperature has been calculated from the Landsat Data for the year 1991, 2001, 2011 and 2017. For all the year, data of month march are downloaded and processed on Arc - GIS, various functions have been assigned to the image to calculate the land surface temperature of the area.

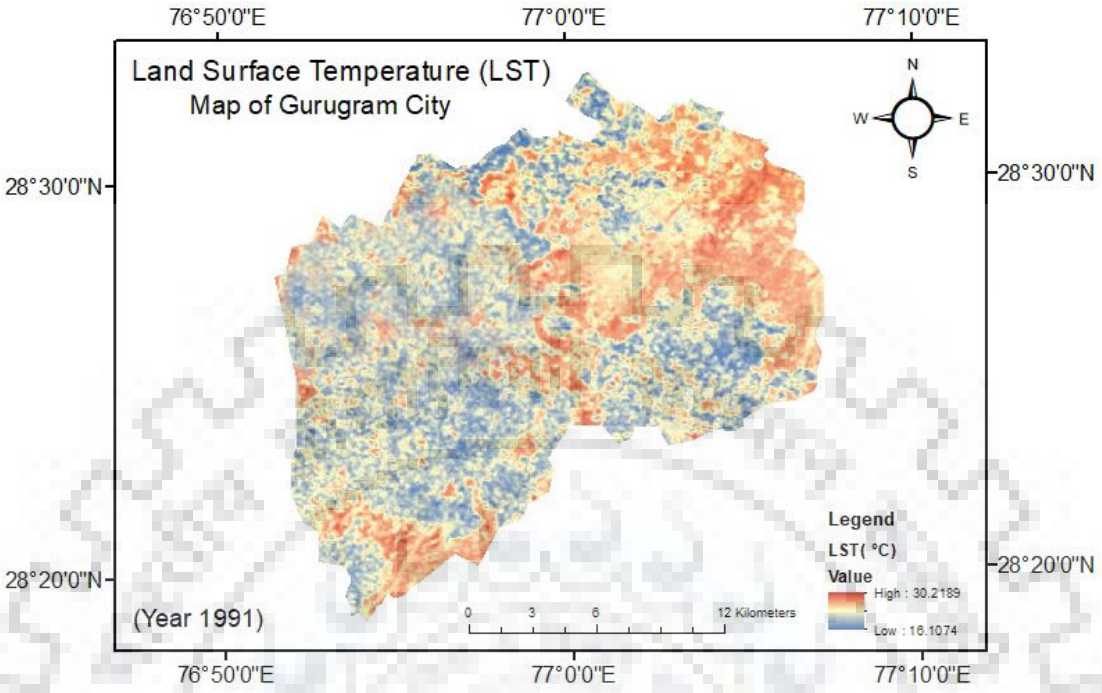


Figure 48 - LST Map of Gurugram of the Year 1991

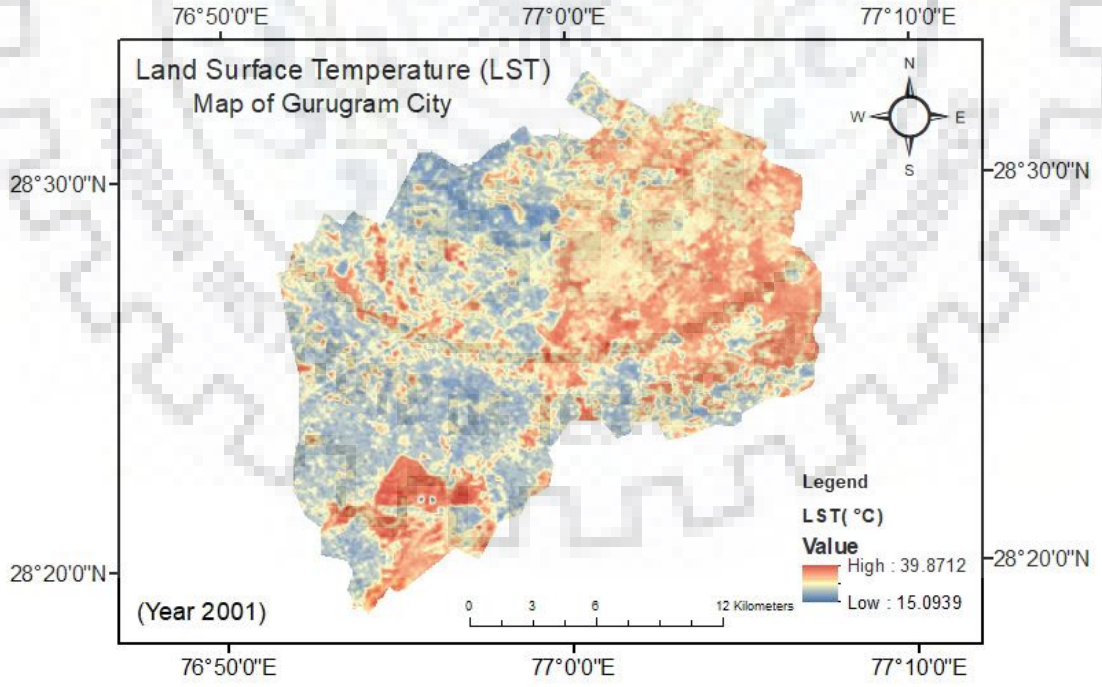


Figure 49 - LST Map of Gurugram of the Year 2001

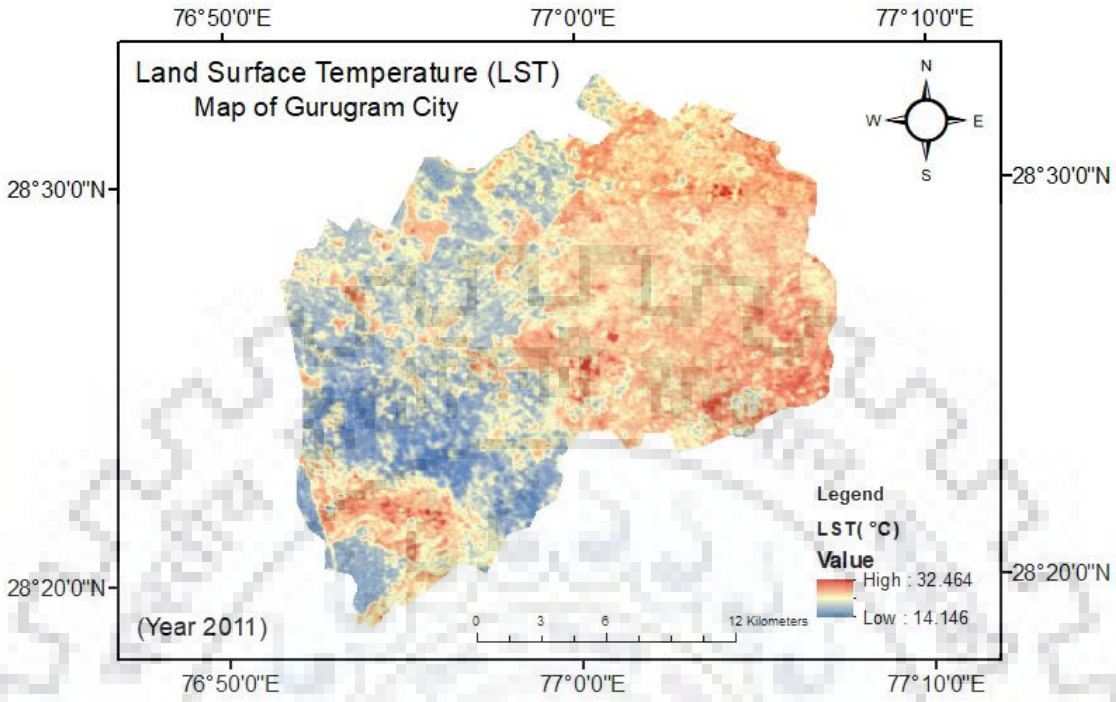


Figure 50 - LST Map of Gurugram of the Year 2011

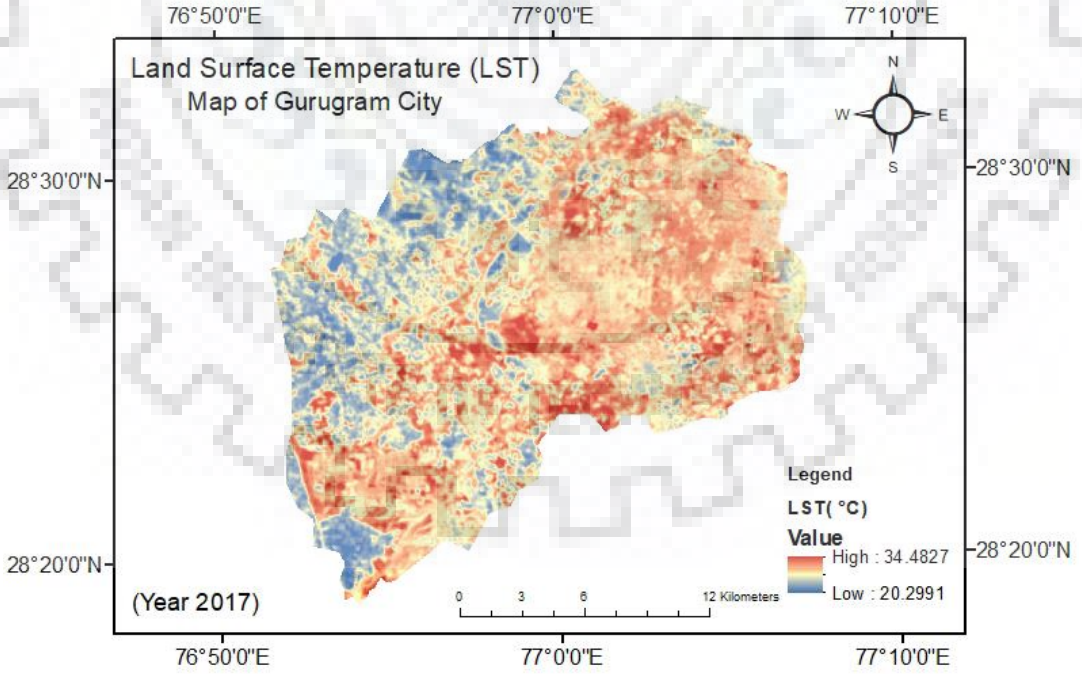


Figure 51 - LST Map of Gurugram of the Year 2017

5.4 Summary

The analysis of weather station data shown increment in temperature value over the years and the analysis of Land Surface Temperature has shown that hat the temperature difference mainly arises in north eastern part of the city where the infrastructure has taken a drastic change in the last 20 – 30 years. In the next chapter a sector from that part of the city has been selected and some strategies have been planned on the identified neighbourhood on the sector.

CHAPTER 6. UHI Mitigation Strategies

6.1 General

This chapter identifies strategies based on literature review & area of interest as discussed in chapter 2 & 3. The strategies have been listed out and characterized according to the decided criteria. Further, it includes finding out possible green zones in selected sector and than design of mitigation strategies that can be applied in identified neighbourhood.

6.2 Mitigation Strategies

Various strategies are listed out for the mitigation process. All strategies have been characterized according to several criteria. The ranking of strategies has been done in matrix form to analyze the best possible strategy to design in the selected area of study. The final conclusion is in the form of strategy basket, in which strategies are listed and clubbed on the basis of the best possible strategies to be implemented first. The mitigation strategies are listed in accordance with respect to the selected criteria.

Mitigation Strategies	Criteria
Ground Vegetation	Effectiveness
Trees in streets	Feasible Cost of Implementation
Medians	Ease of Implementation
Pervious Pavements	Livability
Materials	Maintenance
Water Bodies	Possibility in neighborhood Scale
Urban Park	Residents & Pedestrians Comfort
Green Roof	Aesthetics

Table 3- Various Strategies & Criteria Selected for analyzing best possible option

6.3 Selected Sector

After identification of problem in chapter 5 the area selected to identify green network is sector 12. The area of the sector is 165 acres (0.668 km^2). The land use in the area is mainly mixed type, consisting commercial as well as residential land. The area is in the old city of Gurugram. The major reason to select this sector is that it comes under the area in which there is the maximum change in land surface temperature over the year discussed under section 5.3. The other reason that a lot of this type land use exists in the city where a person spends most of the daily time and therefore these types of land needs to be planned. The public and industrial sector sometimes gets the attention of government to look upon, but the commercial and residential sector does not get that much attention, but to plan these areas is of utmost importance as they compose roughly 70% of land use of the city and thus will be helpful in making the city better.

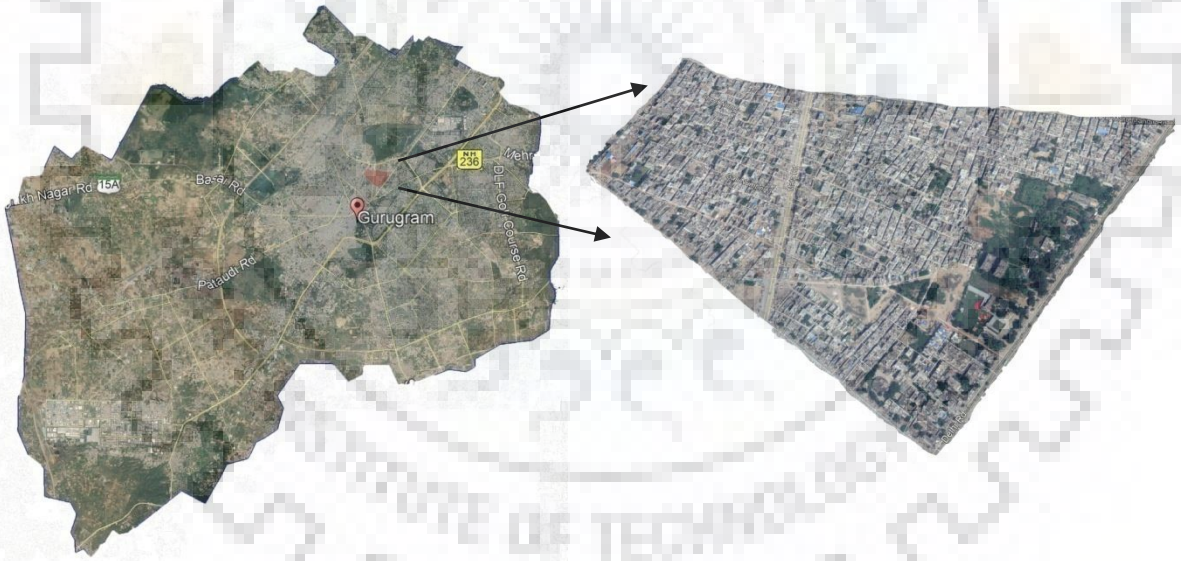


Figure 52 - Selected Sector in the study area

6.2.1 Possible Green Zones

The idea is to convert vacant available land in green zones to manage the green network in the sector and to apply other strategies like to have pervious pavements at the parking areas or on the pathways. To have trees on both the side of the roads, streets and pathways. To implement water fountains and cascades at junctions. To provide shaded seating in open areas. To use a high albedo material on buildings façade. The use of all strategies in the area should be implemented to make the neighbourhood more livable space to live in as these all strategies are helpful in mitigating the effect of UHII.

Figure 53 - Green Zones in Selected Sector

6.4 Design of Identified Neighbourhood

The identified neighbourhood area is represented in fig - 40. The area of the patch is 12 acres (0.05 km^2). This study has been done at the micro level. Various strategies have been designed for the neighbourhood, the same can be designed for other neighbourhood sections.

Figure 54 - Identified Neighbourhood

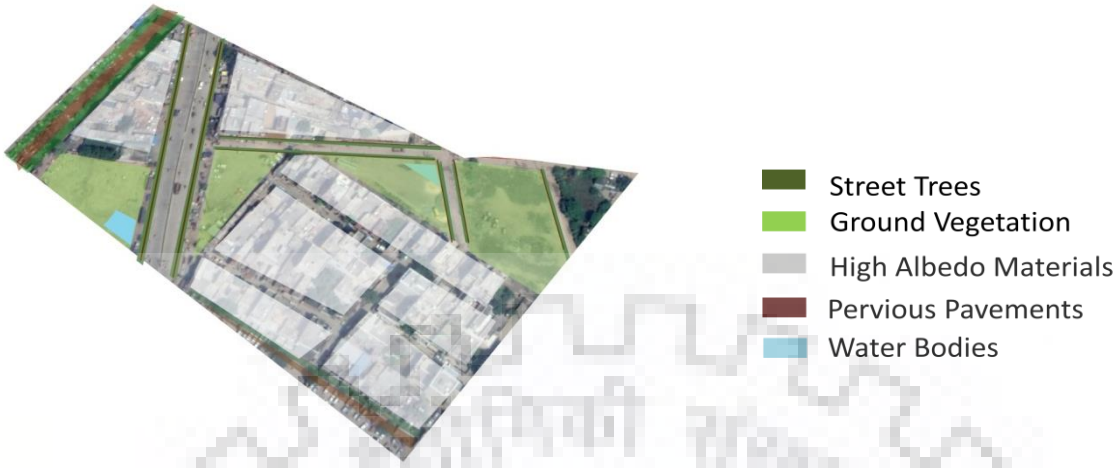


Figure 55- Proposed layout in neighbourhood

Mitigation strategies are designed over selected neighbourhood.The study has been done at local level. The priority is to make these types of land livable so that one can spend quality time in the open environment and if all of these types of land can implement this change, the city would have a great amount of planned areas, more vegetation and hence will have the capacity to fight with effect of UHI.

Figure 56 - Designed Neighbourhood

Figure 57 - Strategies designed

6.5 Summary

Mitigation strategies have been designed on the identified neighbourhood and the same can be implemented in the nearby areas. The strategies have been proven beneficial for mitigating UHI as discussed in chapter 2. The implementation of strategies in the city would be effective for controlling the increase in temperature over the years.

CHAPTER 7. CONCLUSIONS

Among all the mitigation strategies, green vegetation seems to be the most effective measure to encounter UHI effect. In the case of Gurugram, there is vacant and open land available where the ground vegetation can be increased. Tree plantation in the streets of the city helps in reduction of solar radiation. Also, their effectiveness is well proven and widely accepted by the experts as a very much efficient mitigation measures. At the same time, mitigation strategies like the use of high albedo materials and pervious pavements are adopting in the cities as more concrete surfaces are developing. Also, there is opportunity for creating an urban park in the city which would help in creating an effect of Park Cool Island which has the opposite effect that of UHI. Green roofs do not play a major role in this case and would not able to provide sufficient benefit. On the other hand, as a small-scale mitigation measure, like shade trees can be used where there is enough space in the house yard considering its' limitations. Proper planning must have to be done to minimize the effect economically. Presence of water bodies in the city is a controversial issue to some researches and more researches should be carried out for this mitigation strategy. But still it has been noticed that floating water has a significant effect on the surrounding air. Thus, these strategies should be taken in the order for the UHI mitigation.

Green Intervention are environmental friendly that reduces environmental damages produced by using technologies. Green Interventions promises to expand profit while reducing environmental degradation and conserving natural resources Green Interventions should be sustainable technologies which will not create footprint and support the use of natural resources and avoid the production of extra warm gasses. They support automation of every process and hence avoid human intervention. Since they do not support environmental degradation and contribute to creating the footprint, they are sustainable, improves the lifestyle of the people and contribute for human comfortability.

The increased attention to heat-related environment and health issues have helped to advance the development of heat island reduction strategies mainly trees, vegetation, high albedo materials, green and cool roofs, etc. Future policy efforts may focus on encouraging strategies to modify urban geometry and anthropogenic heat in communities to reduce urban heat islands. Research in this area is on-going, and there is a growing awareness of the importance of these factors.

REFERENCES

Adinna, E., Christian, E. I., & Okolie, A. T. (2009), Assessment of urban heat island and possible adaptations in Enugu urban using Landsat-ETM, Journal of Geography and Regional Planning, 2(2): 030-036.

Akbari, H., Pomerantz, M., & Taha, H. (2001), Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas, Solar energy, 70 (3): 295-310.

Bowler, D. E., Buyung-Ali, L., Knight, T. M. & Pullin, A. S. (2010), Urban greening to cool towns and cities: A systematic review of the empirical evidence, Landscape and Urban Planning, 97:147–155.

Cenedese, A. & Monti, P. (2003), Interaction between an inland urban heat island and a sea-breeze flow: A laboratory study, Journal of Applied Meteorology, 42 (11): 1569–1583.

Childs, P. P. & Raman, S. (2005), Observations and numerical simulations of urban heat island and sea breeze circulations over new york city, Pure & Applied Geophysics, 162 (10): 1955–1980.

City of Stuttgart (2008), Climate booklet for urban development.

Cohen, P., Potchter, O., & Matzarakis, A. (2012), Daily and seasonal climatic conditions of green urban open spaces in the Mediterranean climate and their impact on human comfort, Building and Environment, 51: 285-295.

Gedzelman, S. D., Austin, S., Cermak, R., Stefano, N., Partridge, S., Quesenberry, S., & Robinson, D. A. (2003), Mesoscale aspects of the urban heat island around new york city, Theoretical & Applied Climatology, 75 (1–2): 29–42.

Getter, K. L., & Rowe, D. B. (2006), The role of extensive green roofs in sustainable development, HortScience, 41 (5): 1276-1285.

Huang, L., Li, J., Zhao, D., & Zhu, J. (2008), A fieldwork study on the diurnal changes of urban microclimate in four types of ground cover and urban heat island of Nanjing, China, Building and Environment, 43: 7–17.

Kleerekoper, L., Esch, M., & Baldiri Salcedo, T. (2012), How to make a city climate-proof, addressing the urban heat island effect, Resources, Conservation and Recycling, 64: 30– 38.

Kolokotroni, M., Gowreesunker, B. L., & Giridharan, R. (2013), Cool roof technology in London: An experimental and modelling study, Energy and buildings, 67: 658– 667.

Lougeay, R., Brazel, A., & Hubble, M. (1996), Monitoring Intra-Urban Temperature Patterns and Associated Land Cover in Phoenix; Arizona Using Landsat Thermal Data, 11: 79-89.

Moufida, B. & Djamel, A. (2012), Impact of vegetation on thermal conditions outside, Thermal modeling of urban microclimate, Case study: the street of the republic, Biskra, Energy Procedia, 18:73 – 84.

Munich – Future Perspective, (2003), City of Munich, Department of Urban Planning and Building Regulation.

Oke, TR. (1982), The energetic basis of the urban heat island, Quarterly Journal of the Royal Meteorological Society, 108: 1–24.

Oke, T. R. (1988), The urban energy balance, Prog. Phys. Geogr. 12: 471–508.

Offerle, B., Grimmond, C. S. B., Fortuniak, K., Keysik, K., & Oke, T. R. (2006), Temporal variations in heat fluxes over a central european city centre, Theoretical & Applied Climatology, 84 (1-3): 103–115.

Robitu, M., Musy, M., Inard, C., & Groleau, D. (2006), Modeling the influence of vegetation and water pond on urban microclimate, Solar energy, 80 (4): 435-447.

Rozoff, C. M., Cotton, W. R., & Adegoke, J. O. (2003), Simulation of st. louis, missouri, land use impacts on thunderstorms, Journal of Applied Meteorology, 42 (6): 716.

Sailor, D. J. & Lu, L. (2004), A top-down methodology for developing diurnal and seasonal anthropogenic heating profiles for urban areas, Atmospheric Environment 38: 2737–2748.

Sailor, D.J. (2014), Risks of summertime extreme thermal conditions in buildings as a result of climate change and exacerbation of urban heat islands. Build Environment, 78:81–88.

Santamouris, M. (2013), Using cool pavements as a mitigation strategy to fight urban heat island - A review of the actual developments, Renewable and Sustainable Energy, 26: 224–240.

Shashua-Bar, L., Pearlmutter, D., & Erell, E. (2009), The cooling efficiency of urban landscape strategies in a hot dry climate, Landscape and Urban Planning, 92: 179–186.

Simpson, J. R. & McPherson, E. G. (1998), Simulation of tree shade impacts on residential energy use for space conditioning in sacremento, Atmospheric Environment, 32: 69–74.

Spronken-Smith, RA. & Oke, TR. (1998), The thermal regime of urban parks in two cities with different summer climates, International Journal of Remote Sensation, 19 (11): 2085-2104.

Taha, H. (1997), Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat, Energy and buildings, 25 (2): 99-103.

Taha, H. (1997), Modeling the impacts of large-scale albedo changes on ozone air quality in the south coast air basin, Atmospheric Environment, 31:1667–1676.

Tsiros, I. X. (2010), Assessment and energy implications of street air temperature cooling by shade trees in Athens (Greece) under extremely hot weather conditions, Renewable Energy, 35:1866– 1869.

United States Environmental Protection Agency (USEPA) (2008), Reducing urban heat islands: compendium of strategies, urban heat island basics. USEPA, Washington, DC.

Verband Region Stuttgart (2008), Klimaatlas Region Stuttgart.

Voogt, J. A. (2005), How researchers measure urban heat island, Technical report, University of Western Ontario.

Wilmers, F. (1988), Green for melioration of urban climate, Energy and buildings, 3: 660-666.

Yamamoto, Y. (2006), Measures to mitigate urban heat islands, Science and Technology Trends Quarterly Review, 18 (1): 65- 83.

Zoulia, I., Santamouris, M., & Dimoudi, A. (2009), Monitoring the effect of urban green areas on the heat island in Athens, Environmental Monitoring and Assessment, 156: 275-292.

thesis_j

ORIGINALITY REPORT

9%	8%	3%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

article.sciencepublishinggroup.com Internet Source	2%
Reeman Mohammed Rehan. "Cool city as a sustainable example of heat island management case study of the coolest city in the world", HBRC Journal, 2016 Publication	1%
Submitted to University of Southampton Student Paper	1%
www.scribd.com Internet Source	1%
citywindsor.ca Internet Source	1%
docplayer.net Internet Source	1%
mpra.ub.uni-muenchen.de Internet Source	1%
shodhganga.inflibnet.ac.in Internet Source	1%

en.wikipedia.org Internet Source	<1%
Zeleňáková, Martina, Pavol Purcz, Helena Hlavatá, and Peter Blišťan. "Climate Change in Urban Versus Rural Areas", Procedia Engineering, 2015. Publication	<1%
"Counteracting Urban Heat Island Effects in a Global Climate Change Scenario", Springer Nature, 2016 Publication	<1%
sure.geo.unibuc.ro Internet Source	<1%
Submitted to Georgia Gwinnett College Student Paper	<1%
Shrinagesh, B., and Kalpana Markandey. "Rethinking urban space in cities - A study of parks in Hyderabad, India", IOP Conference Series Earth and Environmental Science, 2016. Publication	<1%
www.cugs.in Internet Source	<1%

Exclude quotes On Exclude matches < 20 words