ACKNOWLEDGEMENT

With at most respects and immense admiration, we owe our heartfelt gratitude to our major advisor Mr. Azhar Ali Ashraf, Assistant Professor, Department of Forestry, Sir Syed College Talipparamba, for his guidance, support, advice, inspiration, patience and evaluation, throughout our research work. We had able to learn and develop new skills under his guidance. Besides his support for our research work he had taught us many values and qualities, he had inspired us at many circumstances. We consider ourselves fortunate for being his students.

We express our sincere thanks to Mrs. Sneha C (Head of the Department, Department of Forestry, Sir Syed College, Talipparamba) and Mrs. Haritha, Assistant Professor, Department of Forestry, Sir Syed College Talipparamba, for their valuable time and help they have done to us.

A word of apology to those who have not been mentioned in person and a note of thanks to one and all who worked for the successful completion of this endeavour. Above all, we bow our head before our father and mother whose blessings and care enabled us to complete this programme with great success.

CONTENTS

CHAPTER	TITLE	PAGES
1	INTRODUCTION	1-2
2	REVIEW OF LITERATURE	3-19
3	MATERIALS AND METHODS	20-24
4	RESULTS	25-41
5	SUMMARY	42-43
	REFERENCES	I-XI
	APPENDIX	XI-XXVI

LIST OF TABLE

Table No.	Title	Page No.
1	Urbanization in Kerala and India	6
2	Suggestions for the UHI's causes	12
3	Age class of the respondents	31
4	Perception on factors causing climate change	33
5	Perception of respondents on impacts of climate change	34
6	Opinion of the urban residents on the possible health risks due to climate change	35
7	Opinion of the urban residents on Urban Heat Island	37
8	Opinion of the residents on possible intervention to reduce UHI	38
9	Opinion of the residents on the responsibility of tackling climate change	39
10	Responds of the people on the methods they are willing to adopt to tackle climate change	40

LIST OF FIGURES

Fig. No.	Title	Page no.
1	Map of Kannur District	21
2	LULC – Area (%) graph of Kannur Corporation	25
3	LULC Map of Kannur Corporation	26
4	Comparison of air temperature in different LULC class	27
5	Weekly mean relative humidity during the study	28
6	Urban- Rural temperature difference	29
7	UHI observed	30
8	Probability percentage of respondent's opinion on the changes happening due to climate change	32
9	Probability percentage of respondent's opinion on the factors causing climate change	33
10	Probability percentage of opinion of the urban residents on the possible health risks due to climate change	36
11	Probability percentage of opinion of the urban residents on urban heat island	37
12	Probability percentage of the opinion of the residents on possible intervention to reduce UHI	39
13	Probability percentage of response of the people on the methods they are willing to adopt to tackle climate change	41

1. INTRODUCTION

The rate of population expansion in cities around the world is unprecedented. According to the UN Global Urbanization Prospects 2018, the share of the global population living in cities has increased from 30 percent in 1955 to 55 percent in 2018. In India, there were only 150 or so cities in 1971 with a population of over 500,000 people; by 2015, there were 500 such cities. By 2050, it is anticipated that more than 800 million people will reside in Indian cities if this trend continues (Nandy, 2015). Changes in the Land Surface Temperature (LST) profile and the development of Urban Heat Islands (UHIs), in which urban regions exhibit comparatively higher temperatures than their rural surroundings, are two of urbanization's most significant effects (Ding and Shi, 2013). Urban environments deteriorate as a result of growing urbanization since smaller house lots lead to higher density and less space for greenery.

Land use driven by urbanization alters the urban microclimate and can occasionally have a major impact on precipitation (Pathirana *et al.,* 2014). Urban MicroClimate (UMC) development and the urban heat island phenomena are related. Every town and metropolis, according to Landsberg (1981), has a heat island, which is the most evident climatic indicator of urbanization. Higher air and surface temperatures within the city are also a result of artificial heats emitted by combustion processes from automobiles and industrial activity as well as heat escaping from commercial and home air conditioning. Heat islands have an impact on the energy use, temperature, and livability of communities. Increasing temperatures have an impact on cooling energy demand and hasten the production of urban pollution (Jusuf *et al.*, 2007).

It is evident that cities with poor climatic conditions use more electricity for lighting and air conditioning in the summer. Furthermore, unexpected wind turbulence caused by poorly planned high rise buildings frequently causes discomfort and trouble to the populace due to high temperatures, wind tunnel effects in roadways, and other factors (Bitan, 1992). Many research on urban thermal comfort at the street level show that urban morphology is one of the key elements that influences how a city's microclimate changes (Jain and Pathak, 2019).

Urban temperature changes can be analyzed, specifically in relation to an examination of changes in land-use, thanks to studies on urban microclimate and the urban heat island effect (Ding and Shi,2013). Studies on urban microclimate assist urban planners and designers in creating buildings and improved urban areas that are harmonic with the microclimate and thermal comfort, which is important given that quick and enormous population expansion is anticipated in the near future. To set a standard for the design of adaptation and mitigation actions, it is crucial to assess the current urban heat island (UHI) intensity and distribution.

Many urban green spaces dot the cityscape of Kannur, and it's crucial to understand how this greenery is affecting UMCs. So, in this context, it is crucial to undertake research on the city's linked urban greenery and microclimate, which in turn aids in the district's sustainable urban growth. Based on the aforementioned rationale, the current study's main goal is to examine and analyze the urban microclimates inside the boundaries of the Kannur Corporation and to comprehend how they relate to urban greenery. The attitudes of urban people in the research areas about various aspects of climate change were also explored and analyzed in this study.

2. REVIEW OF LITERATURE

A brief review of the pertinent literature for the study "Analysis of urban microclimates (UMCs) in Kannur Corporation using micrometeorological measurements" is provided here.

2.1. URBANIZATION: A CONCEPT

As a result of industrialization and modernization, urbanization is the process of increasing the percentage of the total population that is concentrated in urban areas (Davis, 1965). Urbanization has been gradual but ongoing in industrialized nations, and it has been followed by changes in agriculture and industry, rising per capita income, and a high standard of living. In contrast, developing nations are urbanizing rather quickly, and this is due more to the expansion of the service sector than to industrialization. According to Macbeth and Collinson (2002), the process of urbanization in developing nations is out of control.

2.1.1 Urbanization in the world

Urbanization is a trend unique to the past few centuries, and it is projected that by 2050, more than two-thirds of the world population will live in urban areas, close to 7 billion people. Currently, over 50% of the world's population lives in urban areas, and by 2030, this number will swell to about 5 billion. Much of this urbanization will unfold in Africa and Asia, bringing huge social, economic, and environmental transformations.

Davis (2006) provides a comprehensive analysis of urbanization in the world, particularly in the Global South. He argues that the rapid urbanization has led to the creation of slums and informal settlements, which are characterized by poor living conditions, lack of basic services, and social exclusion. He further argues that the neoliberal policies adopted by many governments have worsened the situation by promoting the privatization of public services and the exclusion of the poor from the urban economy. Glaeser(2011) gives a more optimistic view of urbanization, arguing that cities are engines of economic growth, innovation, and social progress. He highlights the benefits of density, diversity, and proximity in fostering creativity and entrepreneurship. However, Glaeser also acknowledges the challenges of urbanization, particularly in terms of inequality and environmental sustainability.

The World Cities Report provides a comprehensive overview of urbanization trends and their implications for sustainable development. The report emphasizes the need for integrated approaches to urban planning, which take into account the social, economic, and environmental dimensions of urbanization (World Cities Report 2016). It also highlights the importance of investing in infrastructure, social services, and affordable housing to address the challenges of urbanization. Sassen's (2018) book examines the effects of globalization on urbanization and the resulting socio-economic inequalities. She argues that the global economy is structured in a way that leads to the expulsion of people from their homes and communities, particularly in the Global South.He emphasise how this process is exacerbated by the growing influence of finance capital and the increasing precarity of work.

2.1.2 Urbanization in India

Urbanization in India has been on the rise since the beginning of the 20th century, with the pace of urbanization growing faster from 1931 onwards. The proportion of urban population rose from 11.9% in 1931 to 19% in 1961, with the maximum increase taking place in the decade 1941-1951. India has shown an unprecedented increase in the urban population in the last few decades, with its urban population increasing about 14 fold from 1901 to 2011. While the growth is mainly uneven, it is not skewed and not concentrated to a single city of the country. Urbanization in India is generally accomplished in two ways: first, by natural population growth in urban areas, and second, through rural-to-urban migration.

The economic policy of 1991 caused a rapid expansion of the economy that is mostly concentrated in urban areas, which causes a migration of people from rural areas to urban areas. Hence, unlike western nations, India's urbanization process was quick and unplanned, as opposed to the later where it happens gradually (Sadasivam *et al.,* 2016). According to Nijman (2012), rather than the attractiveness of industries in urban regions, the rural-urban movement is mostly caused by the agricultural sector's underdevelopment. While smaller towns and less developed areas are stagnant in the urban expansion, urbanization phenomena appear to be escalating in already urbanized Indian metropolis (Kundu, 2011).

In India, there were only five cities with a population of one million or more in 1951; by 2011, that number had increased to 53 cities, and by 2031, it was expected to reach 70 cities. Six cities are anticipated to reach a population of 10 million by 2031, up from three in 2011 that had more than 10 million residents. It is predicted that by 2030, there would be 610 million people living in urban areas, or 40% of the nation's total population (Mohan, 2012). According to Jaysawal and Saha's (2014) hypothesis, Indians make up one in twelve urban dwellers and one in seven people from developing nations. India has 393 urban agglomerations in 2010 and 465 by 2011. Urban agglomerations are defined as cities with a population of one million or more.

With 97.5% of its people living in urban areas, Delhi is India's most urbanized city, followed by Chandigarh (97.25%). In terms of the proportion of its people living in urban areas, Tamil Nadu leads India with 48.45%, followed by Kerala and Maharashtra with 47.72% and 45.23%, respectively. India has seen rural poverty-driven urbanization, which is an involuted sort of urbanization rather than the kind that evolved in affluent nations. The lack of urban functional qualities and urban wealth in India's urbanization is what led to the growth of slums in its megacities. And it failed to supply the urban population, particularly in Indian megacities, with essential facilities like housing, drinking water, and power (Kundu, 1999).

2.1.3 Urbanization in Kerala

According to Census 2011 data, Kerala is now the major Indian state with the second-highest percentage of urban residents. Kerala's proportion of urban residents increased quickly from 25.96% in 2001 to 47.72% in 2011 (Anon, 2011). Both the growth of census towns and the organic growth of the state's urban population are to blame for this increase. To such a tremendous expansion in urbanization, the natural increase in urban population has a very small impact.As a result of many rural regions being reclassified as urban, moving from villages to census towns, there was a dramatic increase in the number of people living in cities between 2001 and 2011. The census towns increased from 99 in 2001 to 461 in 2011.

The main factor contributing to the growth of census towns has been the exodus of male workers from the agricultural sector. These 461 census towns are all village Panchayats in terms of jurisdiction. A State Urbanization Report, just released by the Town and Country Planning Department, describes Kerala's current level of urbanization as urban spread rather than modifications brought on by any fundamental changes in the state's economy (Kerala government, 2011) (Table.1). It also discusses the difficulties in maintaining the economic foundations of rural and urban communities as well as the relationships between them. Nevertheless, this problem goes beyond only how urban and rural areas interact. Kerala has historically adopted a continuum of rural to urban habitation patterns (Sreekumar T. T., 1993). The issue is what kinds of issues census towns are encountering and whether or not these towns' village Panchayat local administrations are equipped to handle them. In addition to having the authority, capabilities, and responsibilities of a rural local government, census towns' local governments will also face issues like to those faced by smaller metropolitan local governments in terms of providing infrastructure and public services.

Table.1: Urbanization in Kerala and India, 1961-2011

Census	Degree of urbanization in Kerala	Degree of urbanization in India
1961	15.11	17.97
1971	16.24	19.91
1981	18.78	23.34
1991	26.44	25.71
2001	25.96	27.8
2011	47.72	31.1

2.1.4 Impacts of urbanization

Urbanization and the resulting degradation of the urban water environment have a substantial historical record in the United Kingdom, which only started to ameliorate with technology and environmentally conscious laws in the latter 20th century (Johnstone and Joran, 1996). Poor urban water quality is still a problem, especially in light of population growth, the emergence of new, unregulated substances, the increased value placed on ecosystem services (Green *et al.,* 2015), and uncertainty regarding the effects of climate change on water quality-controlling factors like temperature and environmental flows (Acreman and Ferguson, 2010, Arnell *et al*., 2015).

In several studies and reviews (e.g. Praskievicz and Chang, 2009; Hunt and Watkiss, 2011; Kundzewicz *et al.,* 2013), the effects of climate change and urban water environments have been discussed on a global level. These studies and reviews highlight the difficulties that come with a combination of climate change and rapid urban development. Despite a long history of river gauging in the UK, Hannaford (2015) concludes that trends are influenced by natural variability and that it is impossible to link observed changes in peak flows to climate change. The single event-based attribution study that was conducted evaluated the autumn 2000 flood event and concluded that anthropogenic greenhouse gas emissions are likely to have enhanced the likelihood of flooding (Kay *et al*., 2011). Because there are no correlations between climate change and high flows and because there aren't enough long-term records, the IPPC decided that it is only with a low degree of confidence that it can be said that anthropogenic climate change has altered flood frequency and magnitude (IPPC, 2014).

Climate change's additional effects: In the UK, the majority of research on the effects of climate change has been concentrated on catchments with problems related to mining pollution and dispersed agricultural difficulties (Macleod *et al.*, 2012). (e.g. Foulds *et al.,* 2014). The majority of persons who analyse metropolitan areas do so inadvertently by using the research catchment region. Large urban areas in the Thames basin were modelled using Future Flows river flow projections (Prudhomme *et al.*, 2012a) and the Questor, Hutchins *et al.,* (2016a) water quality model, which revealed decreased low flows (Q95) and an increase in the number of days that violated water quality standards for dissolved oxygen (DO), BOD, and chlorophyll.

According to some studies, urbanisation and climate change together will make extreme weather more common and more powerful.Other studies show that urbanisation, as a result of projected increases in per capita water consumption and more uncontrolled discharges, will have an impact on the frequency and size of events that exceed thresholds for DO and NH4 concentrations, primarily by increasing rainfall depth rather than intensity (Astaraie-Imani *et al*., 2012; Whitehead *et al.*, 2013).

2.2 MICROCLIMATE: AN OVERVIEW

Microclimate refers to the climate of a small area, typically less than a few kilometers in size. It is influenced by local factors such as topography, vegetation cover, and human activities, and can differ significantly from the climate of the surrounding region. Some of the key characteristics of microclimates include: temperature, humidity, wind, precipitation, air quality . The word "microclimate" refers to the surrounding physical conditions brought on by atmospheric variables, which encompasses all the circumstances created by both natural and artificial driving factors (Camuffo, 1998).

It is also discribed as a small-scale climate of any specific location, such as a park, city, valley, small town, etc. that is distinct from its surroundings, according to Mislan *et al., (*2008). The main atmospheric factors affecting microclimate are temperature, precipitation, humidity, and sensible latent heat fluxes, all of which are influenced by human activity. Depending on the local circumstances, atmospheric variables change.It is impacted by surface characteristics as well as atmospheric factors. The closest features, especially those within 10 meters, have the biggest impact on the microclimate. These elements may be created by humans, such as parks, buildings, or natural features like waterbodies, grasslands, and trees (Mahmoud, 2011).

2.2.1 Urban microclimate

The quality of life of urban dwellers is directly impacted by the urban microclimate. An increasing amount of natural surfaces have been occupied and replaced by man-made surroundings as a result of urbanization. Urban industrialization intensifies under such conditions, and urban population growth is rapid.

Heat emissions from increased industrial production and population growth are significant, and the city's inadequate ventilation is made worse by the dense building complexes.The resulting heat island effect will cause urban temperature anomalies that elevate energy and water use and have an impact on the near-stratigraphic atmospheric circulation, which will exacerbate air pollution. Urban biophenology and ecological processes are negatively impacted by this influence in varying degrees. The quality of life and health hazards for urban dwellers are among the effects that the heat island effect can have on cities. According to Jiajing Li *et al.*, (2022) people who live in hot climates are more prone to experience physical discomfort, sleeplessness, and heat cramps than people who live in cold climates .

2.2.2 Factors influencing urban microclimate.

Urban microclimate variables include air temperature, wind speed, humidity, and sun radiation. The most straightforward factor is air temperature, which is also relatively simple to measure and forecast. As a result, weather reports frequently include air temperature information. Even with something so obvious, things become slightly more complex when we dig a little deeper. The majority of weather forecasts typically give the air temperature 10 metres above the ground, which is the completely mixed average air temperature, without taking any ground influence into account. It becomes immediately obvious that air is not completely mixed where people often move around if you imagine hot air wobbling over pavement on a hot summer day.The cause is that air is heated directly by hot surfaces, which are then heated by the sun, rather than by the sun itself. Thus when air comes into contact with hot objects, it becomes substantially hotter. Just picture an automobile that has been left out in the sun for a while. Hence, even if the meteorological air temperature is crucial, the situation can be extremely different in an urban setting due to the numerous surfaces and fluctuating wind speeds.

One of the main influencing factors is wind speed. In essence, it establishes how quickly our bodies would warm to air temperature in the absence of radiation and evaporation. If the wind is stronger, more of the relatively chilly air particles come into touch with our body, which has a cooling impact because the air temperature is often lower than our body temperature.

This can cause a serious wind chill in the winter due to the extremely low air temperatures and high winds. On the other hand, throughout the summer it prevents us from becoming too hot. Yet, the effect in the summer is not solely due to the cooler air temperature, but also because moving air (typically) aids in the evaporation of moisture from our skin.The main component of the cooling effect of wind in summer is the energy required for the evaporation process, which is absorbed from our bodies (much as when you evaporate water on a stove).

After discussing evaporation, we now go on to the topic of humidity: Only when the air is not already completely saturated with moisture is it possible for moisture from our skin to evaporate into the atmosphere; evaporation also becomes slower the more saturated the air is. Relative humidity tells us just this. This cooling mechanism is impossible at 100% humidity since the air is entirely saturated and water does not evaporation from our skin (or anywhere else) any longer. In contrast, water may easily evaporate from the skin in dry heat, making it simple to cool down. This is only true, though, provided there is enough air flow; otherwise, the air around our bodies becomes suffocated. Radiation adds yet another layer of complexity to everything else.When you are sitting in front of a fire on a chilly night, infrared radiation is most noticeable on your skin. On sunny days, it is typically just solar radiation. When shady on a hot, sunny day, the direct impacts of solar radiation are easily felt. Reflected radiation from the ground and structures can also have a significant impact on the built environment. In addition to the acute impacts that occur during the day, secondary radiation also contributes significantly to the urban heat island at night. Cities remain substantially warmer because heat radiation bounces off of nearby structures rather than dissipating into space as it would otherwise.

2.3 URBAN HEAT ISLAND

Urban heat island (UHI) and urban pollution island (UPI) are two examples of the substantial changes in human habitation, energy use, transportation, and industry patterns as well as the strain on natural resources brought on by rapid urbanisation, population growth, and ongoing encroachment into the unbuilt space (Imhoff *et al.*, 2010; Izrael *et al.,* 1990). The thermal balance in urban areas differs from nearby rural areas due to changes in heat and momentum transfer between the land surface and the atmosphere, including changes in heat storage, the division of sensible and latent heat fluxes (Bowen ratio), frictional drag, and the ratio of natural and anthropogenic emissions (Vailshery *et al.,* 2013; Dousset and Gourmelon, 2003).UHI intensity (UHII, calculated as the temperature difference between a representative urban area and the rural background) can reach 11/12 °C with an average cooling penalty in urban versus rural buildings of 13.1%, a peak electricity penalty per degree of temperature rise of 0.45% up to 4.6%, and an electricity penalty per degree of temperature rise and per person of 21 (10.4) W/°C/person (Santamouris, 2015; Santamouris and Kolokotsa, 2016). (2015) Santamouris *et al.,* If we factor in the fact that the usual cooling energy requirements of residential and commercial buildings will rise by 750% and 275%, respectively, in about 30 years, we can estimate the expected consequences (Santamouris, 2016).

2.3.1 Factors influencing UHI

Urban heat island phenomenon has grown to be a major problem for many places across the world. Cities in wealthy nations have long been aware of the emergence of heat islands. But, as urbanization increases, heat islands are also being seen in both big and small towns in developing nations.

Controllable and uncontrollable factors were distinguished by Rizwan *et al.,* (2008) when categorizing factors affecting UHI. Moreover, it is divided into three categories: cyclic impact variables, permanent effect variables, and temporary effect variables. Wind speed and cloud cover are the variables that have a brief effect. The variables that have a long-term impact include things like sky view factor, building density, and green space. Both solar radiation and heat produced by human activity are cyclic effect variables.In contrast to direct solar heating, which provides equal heating to both urban and rural areas, indirect solar heating increases the creation of UHI. Indirect solar heating (ISH) refers to the increase in urban temperature caused by the storage of solar energy by built-up areas and the later release of that energy. One of the key elements influencing indirect solar heating is surface albedo. All of these manageable and unmanageable elements together form UHI.

The objective of this study is to comprehend and evaluate the proportional contributions of the causal elements and their interactions to the UHI intensity. The three key factors—anthropogenic heat, impervious surfaces, and three-dimensional (3D) urban geometry—are reclassified in accordance with earlier findings. The three subfactors of the 3D urban geometry factor—additional heat stored in vertical walls, radiation trapping, and wind speed reduction—are further investigated. According to Table.2, this is a new classification of the causes of the UHI. The next part goes into more detail about the contributing elements.

Table.2 : Suggestions for the UHI's causes.

Causative factors	**Description**
Anthropogenic heat F1	Additional heat released by human activities
Impervious surfaces F2	reduction in surface moisture availability increase in thermal inertia of urban surface materials
Three dimensional urban geometry F3	
Additional heat stored in vertical walls G1	additional surfaces in the vertical (walls) that are able to absorb and store heat
Radiation trapping G2	Increase in absorption of short wave radiation and decrease in loss of long wave radiation within an canyon
wind speed reduction G3	wind speed reduction above and within an urban canopy layer due to the existence of buildings

** F1, F2, and F3 stand for the primary factors, and G1, G2, and G3 stand for the secondary elements.*

2.3.2 Studies on UHI across the world

1) UHI in the USA

According to Karl *et al* .'s investigation of the connection between urbanization and climate, even small American towns' climate records have been impacted by urbanization. The impact of urbanization on the US climate record was examined using two distinct methods using monthly averages of maximum, minimum, and average temperatures from 1219 stations. Urbanization was found to be a primarily nighttime phenomenon on the Historical Climatology Network during the 20th century (1901-1984), and it appeared to have little impact on the maximum temperature. However, it had a significant impact on the diurnal minima, means, and range, amounting to 0.06°C (average), 0.13°C (minimum), and - 0.14°C (diurnal).More than 85% of the stations in the Historical Climatology Network (HCN), a station network with a population of less than 25000 in 1980, are situated in rather rural areas. The growth rate of these stations was rather slow over the 20th century. Findings from network subsets show that biases in rapidly expanding metropolitan regions are substantially bigger. Cities with a population of 10,000 people or less had an average yearly temperature that was 0.11°C warmer, 0.32°C warmer, and 0.91°C warmer than those with 100,000 or more residents.

According to Jones *et al.,* analysis .'s , a significant portion of the northern hemisphere has had an urbanization impact on temperature time series of 0.05°C/100 years. Based on the study of Karl *et al.,* for the United States, which revealed an urban influence of 0.15°C for the period 1901–1984, this result was further examined using data from eastern Australia, eastern China, and European regions of the Soviet Union.Based on information from the Defense Meteorological Satellite Program Operational Line scan System, Gallo *et al.,* Examined groups of the 1221 weather observation stations that make up the US Historical Climatology Network and are classified as urban, suburban, or rural. The satellite-based classifications of land use and land cover were based on temperature patterns and anthropogenic visible light radiated from the earth's surface. The Historical Climatology Network's two other land use/land cover categories and the serial temperature data set for the years 1950–1996 were compared.

2) UHI in Asia

Using MODIS data, Jiahua and Fengmei researched the UHI in Beijing (China) and found that in the summer, there is a land surface temperature differential of around 4-6°C between the city and the suburbs and 8–10°C between the city centre and the northwest far (outside) suburbs (evening or late night). The significant variation in temperature between urban and suburban areas is a result of heat being absorbed and deposited on the surface.

Using a combination of Advanced Spaceborne Thermal Emission, Reflection Radiometer (ASTER) and Thematic Mapper (TM) data, Cai *et al.,* also discovered the UHII in Beijing from 2002 to 2006. Their findings demonstrated that the UHI effect throughout time has not been proportionate to urbanization. Overall, the spring, summer, and fall in metropolitan Beijing are characterized by a high UHI effect. The majority of Beijing's neighborhoods have a significant UHI effect, particularly those that are industrial and home to several enterprises, including iron and steel, thermoelectric, and foundries. The high density of manufacturers, which use a lot of heat, results in higher temperatures.

3) UHI in the Africa

With his analysis of the UHI in Johannesburg, Goldreich turned his focus to Africa (South Africa). Throughout 1966 and 1967, an intensive transportable equipment was used to measure the wet and dry bulb temperatures at noon and just before dawn. In the city center, which was almost 11°C warmer than the northern suburban valleys, a substantial UHI and humidity were evident during strong-inversion winter nights (dry season), according to the results. The relative humidity was 43% lower than in the rural areas, and the UHII was predicted to be around 5°C. In the 1970s and 1980s, upper air studies using a helicopter and tethered bal- loons were conducted as part of a second phase of the project.

In three stations with mercury thermometers, Robaa studied the UHI in Cairo (Egypt) for the years 1995 to 2000. He discovered that while the urban environment was consistently drier than the suburban environment in the morning, it was more humid in the afternoon. Throughout the year, the urban environment was warmer than its environs, with the exception of November, when a chilly island appeared. Finally, from February to September (except May), the urban area was drier than the rural area, and the monthly mean UHI ranged from 1.0°C to 2.2°C. During the cold season, from October to January, the UHII was equal to about 1°C.In three stations with mercury thermometers, Robaa [93] studied the UHI in Cairo (Egypt) for the years 1995 to 2000. He discovered that while the urban environment was consistently drier than the suburban environment in the morning, it was more humid in the afternoon. Throughout the year, the urban environment was warmer than its environs, with the exception of November, when a chilly island appeared. Finally, from February to September (except May), the urban area was drier than the rural area, and the monthly mean UHI ranged from 1.0°C to 2.2°C. During the cold season, from October to January, the UHII was equal to about 1°C.

4) UHI in Australia

Morris and Simonds examined the prevalence of UHI in Melbourne in neighboring Australia. According to the authors, UHII varies depending on location, time of day, and year from a mean of roughly 2-4°C to daily maxima as high as 7°C. The central business district in Melbourne had a peak warming of 7.1°C in 1992, with smaller peaks observed in industrial regions and medium-density terrace housing in the inner northern suburbs.When the daily minimum temperature was higher than 24°C, research found that there were more excess deaths (up 19–21% over the predicted mortality rate) . In Melbourne, three urban sites with increasing urban density and one rural control site were constructed as part of four research sites. Each urban site's surface parameters, including the amount of impervious surface, albedo, height to width ratios (which determine how an urban canyon is shaped), and surface energy balance (which includes energy from evapotranspiration, heat storage, and atmospheric heating), were studied. Evapotranspiration was observed to vary greatly between urban and rural locations, which resulted in baseline variations in the UHII between the two settings .

5) UHI in Europe

The daily temperatures in London, England, in 1820 were examined by Howard. These data show that London's daily temperature in July was 0.6°C higher than its surrounds, and it was 1.2°C higher in November. Howard emphasized that the difference in temperature between the city and the country was 0.18°C during the day and 2.05°C at night. The transition from a heat island to a cold island and diurnal/seasonal variation were the first scientific proof of temperature anomalies .

In general, Chandler and Landsberg conducted investigations on London's UHI from the middle of the 1960s to the beginning of the 1980s and reported the presence of a UHII of 4- 6°C during the night. The temperature difference between St. James's Park and Wisley (London) was studied by Lee between 1962 and 1989. He discovered that during the summer, the daytime UHII decreased over time, from about 0.5°C down to 0.25°C, while the nighttime UHII rose by about 0.5°C .

The UHI in Lodz (Poland) was explored by Klysik and Fortuniak. Data from three sites at Lodz University's Department of Meteorology and Climatology were utilized. The authors came to the conclusion that more than 80% of nights are marked by excessive heat in towns, measured as a UHII of 2°C to 4°C and up to 8°C. The authors compared data from two different time periods: (a) three years in the early 1990s between an airport station and a station in a large downtown square; and (b) three years in the 1930s between the same airport station and a meteorological station operating in the city center on the edge of a small park. They came to the conclusion that the UHII in the 1930s had roughly similar dimensions.

2.3.3 Impacts of UHI

2.3.3.1 UHI Impact on Environmental Dimension

According to certain studies, UHI can cause precipitation and flash floods. Depending on the size of the metropolitan center and the physical factors surrounding it, UHI caused a 28% increase in monthly rainfall within 30-60 km of the metropolis (Shepherd *et al.,* 2002). The high temperature in the urban center causes convection, which increases rainfall there. Urbanization-induced UHI increased Atlanta, USA's cumulative rainfall by 10–13%, according to Lin *et al.,* (2008).

Urbanization in the Yangtze River delta region of China has caused an average temperature increase of 1.490C in the summer and 0.70C in the winter, respectively. It has also been noted that the number of days with high temperatures has increased to 3.7 days annually as a result of UHI (Zhong *et al*., 2017). One of the issues exacerbated by UHI is the heatwave. Dehydration, tiredness, and even death, can result from it. According to predictions, climate change will cause more heatwaves to occur more frequently and to stay longer (IPCC, 2014). Urban heat islands (UHI) increase the dangers associated with heatwaves (Tan *et al.,* 2010).According to Zhao *et al*., (2018), UHI is 80% greater during heatwave days than on other days, increasing by 0.4 0.050C. UHI and Heatwave's additive effect raised mortality risk by 2.2%. (Anderson and Bell, 2011).

2.3.3.2 UHI impact on social Dimension

Cities' increased energy usage is a result of urban heat island. One-sixth of the electricity produced in the US, according to Rosenfield (1998), is used to cool buildings; of this, nearly half of the electricity demand comes from the cities where the urban heat island phenomenon is visible. According to him, the UHI can increase cooling energy use by 19%. Additionally, he discovered that this differs in metropolitan areas and cities. In bigger Ethans, Hassid *et al.,* (2000) predicted a 15–50% increase in cooling energy.While in Bahrain, UHI was responsible for a growth of 2-10%. (Radhi *et a*l., 2013). According to Skelhorn *et al*., (2016), UHI causes an increase in air conditioning load of 9–12% during the summer. He also calculated that a 5% increase in mature tree cover will reduce UHI by 0.10C. The UHI will result in a decrease in heating demand while an increase in cooling and energy consumption. The demand for cooling energy would result in a 500% rise in CO2 emissions in urban areas by 2050. (Kolokotroni *et al.*, 2012).

The effects of UHI phenomena can become more severe. According to Taylor *et al.,* (2018), the west midland of the UK experienced a 21% increase in UHI-induced mortality. According to Rocklov *et al*., (2014), urban dwellers' respiratory illnesses can worsen as a result of urban heat islands' increased temperature.

2.3.3.3 UHI impact on the economic dimension

Increasing heat stress at work can lower labor productivity by impairing decision-making, exhaustion, and focus (Smith *et al.*, 2014). According to Zander *et al.*, (2015), heat stress caused 7% of people to miss work for at least one day, and 70% of workers reported being less productive. Kjellstrom *et al*., (2016) estimate that the effects of heat islands reduce work capacity by 10% during the day.According to Klepper and Peterson's 2008 estimate, the financial loss resulting from decreased labor productivity owing to heat stress ranged from US$ 0.77 to 3.4 billion. In Australia, heat stress costs 0.33 to 0.47 percent of the country's GDP (Zander *et al*., 2015). He also came to the conclusion that in the future, the labor productivity in hot months will decline by 11–17% in Asian countries. When the temperature rises above this range, productivity begins to suffer. The ideal temperature for indoor work is between 21 and 22 °C. Productivity drops by 8.9% at 30°C (Seppanen *et al*., 2006).

2.4 THE IMPACT OF VEGETATION ON THE URBAN ENVIRONMENT

Urban vegetation influences pollution deposition and dispersion, which has an impact on air quality. Many experiments and simulations that have been conducted on-site and in wind tunnels, focusing on things like urban street canyons and crossings or vegetation barriers next to traffic sources, have been developed to characterise both processes. Detailed empirical descriptions of parameters that are outside the study's stated focus are urgently needed, as well as well-structured experimental data (Sara Janhäll, 2015).Urban vegetation is currently favoured because of the ecosystem services it may offer, such as lowering flooding issues. Although reduced dilution is frequently overlooked, positive impacts on air quality through filtration of contaminated air are frequently emphasised.

Many cities are progressively considering urban greenery in their planning as a strategy to mitigate the effects of climate change, such as the rising sea level and global warming (Andersson-Sköld *et al*., 2015).Particle deposition on vegetation (Litschke and Kuttler, 2008); dry deposition on plant canopies (Petroff *et al.*, 2008a); urban green space and social justice (Wolch *et al.*, 2014); and dispersion without the complexity of vegetation (Wolch *et al*., 2014) are a few topics on which reviews have been published (Xia *et al*., 2014). Although the impact of vegetation on urban air quality is still not fully understood, numerous studies have attempted to evaluate the economic benefits of improving air quality (Tiwary *et al.,* 2009, Escobedo *et al.*, 2011).

3. MATERIALS AND METHODS

The goal of the current study, "Analysis of Urban Microclimate in Kannur Corporation using Micrometeorological Measurements and Remote Sensing Data," was to determine how the city's urban microclimate and urban heat island were developing. The survey also looked into how urban residents felt about climate change.

3.1 STUDY AREA

The Keralan city of Kannur (Cannanore) is governed by the Kannur Corporation, commonly referred to as the Corporation of Cannanore. E. P. Latha served as the Corporation's first mayor after it was founded in 2015. The two assembly districts that make up the Kannur Corporation are Azhikode and Kannur (State Assembly districts), both of which are a component of the Kannur parliamentary district. The Corporation, which is led by a mayor and council, is in charge of the 78.35 km^2 of Kannur City, which is home to roughly 232,486 people. The Kannur Municipal Corporation was established with the goal of enhancing the town's infrastructure.

According to a report issued by Census India 2011, the Kannur Municipality has a population of 56,823, of which 26,298 are men and 30,525 are women. Latitude and longitude coordinates of Kannur corporation are: 11.874477, 75.370369 (Fig.1).

3.1.1 Climate

An extremely wet tropical monsoon climate (Köppen classification Am) prevails in Kannur. The daily maximum temperature in April and May is approximately 35°C (95 °F). In December and January, the temperature averages around 24 °C or 75.2 °F.

3.1.2 Demography

39 wards make up the city of Kannur, and elections are held in each one every five years. According to a report issued by Census India 2011, the Kannur Municipality has a population of 56,823, of which 26,298 are men and 30,525 are women.

Fig.1:Map of Kannur district

3.2 PREPARATION OF LAND USE LAND COVER (LULC) MAP

Land Use/Land Cover features were extracted by on-screen digitization and visual interpretation. Landsat 8 OLI data of 30m resolution acquired from Earth Explorer was used to study the land use land cover of the area. Data for the time period 29 January 2021 was taken to do the LULC classification. The images were classified into 9 LULC classes, namely Urban_compact, Urban_sparse, Urban_vegetated, Industrial, Fallow land, Plantation, Scrubland, Cropland and Water body. The LULC classification system adopted for the study is broadly based on NRSC-LULC classification system with somemodifications to suit the study area.

3.2.1. LULC class

1. Urban_Compact: When more than 80 % of the surface area is occupied by the urban structures and transport network (i.e., impermeable surfaces) and the remaining area is open land or covered with vegetation then it was assigned as Built-up-compact.
2. Urban _Sparse: Around 40 to 80% of the land is covered by the structures like buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, occupying discontinuous but significant surfaces.

3. Urban _Vegetated: These are highly vegetated areas situated within urban agglomeration or in contact with urban areas with urban surfaces less than 40%. This includes: Parks, sports and leisure facilities, camping grounds, sports grounds, golf courses, race courses etc.
4. Industrial: These are artificially surfaced areas (with concrete, asphalt, tar macadam, or stabilised, e.g., beaten earth) without vegetation, which also contains buildings and/or vegetation. These are commercial manufacturing units along with other supporting establishments of maintenance.
5. Fallow Land: Fallow lands are agricultural land but remain fallow for a short period or temporarily remain uncultivated for one or more season.
6. Plantation: These are the areas under agricultural tree crops planted adopting agricultural management techniques. These also includes the areas of land use systems and practices wherein cultivation of herbs, shrubs, and vegetable crops are deliberately integrated with agricultural crops mostly in irrigated conditions for ecological and economic reasons.
7. Scrub land: This is a land, which is generally prone to deterioration due to erosion or anthropogenic activities. Scrublands are associated with moderate slopes in plains and foot hills and are generally surrounded byagricultural lands. Depending on the vegetation cover it is further classified as Dense and Sparse.
8. Cropland: These are the lands primarily used for agricultural purposes. It includes land under crops both irrigated and unirrigated. In a broad sense, croplands may be defined as those lands which are cultivated to produce food crops and related activities
9. Water body: The natural course of water flowing on the land surface along a definite channel/slope or impounded in the form of ponds, lakes and reservoirs.

3.3. SELECTION OF SITES FOR IN-SITU MEASUREMENTS

Three significant LULC classes from the Kannur corporation were found on the LULC map created for the study region. They were densely populated, sparsely populated, and vegetated. From each of these three classifications, three sites were chosen for the in-situ measurements. Relative Humidity and the daily ambient air temperature were measured at the locations. The air temperature and relative humidity were determined using a whirling psychrometer.

3.3.1 Whirling psychrometer

The two thermometers that make up the spinning psychrometer, also known as a sling psychrometer, are fastened to a frame that revolves around a handle, allowing it to be spun in the air by hand.

One thermometer is covered with a snug-fitting muslin sock and kept damp with water. Wet-bulb thermometer is the name of this muslin-covered thermometer. The dry-bulb thermometer is one that is directly exposed to the atmosphere. The dry bulb displays the temperature of the surrounding air. Wet bulb and dry bulb temperatures are used to compute relative humidity. Using a chart, the relative humidity can be determined from the wet-bulb depression.

3.4 ESTIMATING URBAN HEAT ISLAND INTENSITY

The differential in ambient air temperature between an urban area and a nearby rural area is known as an urban heat island (Oke *et al.,* 1972). Three area were taken as a reference point (rural area) for estimation of UHI.

$$\text{UHI } (\Delta T^{\circ}C) = T_{urban} - T_{rural}$$

T = Temperature in ºC.

3.5 PERCEPTION STUDY

Only through guaranteeing that people are involved in solving the problem will climate change be reduced. In order to create solutions to the issue of a changing climate, it was thought that how people view climate change was essential.

3.5.1 Selection of respondents for survey

Urban dwellers participated in the survey. Residents of the Kannur Corporation were considered to be city dwellers. Following that, 30 residents were chosen at random for in-depth interviews to learn about their perspectives on climate change.

3.5.2 . Collection of primary data

To collect information about people's understanding of climate change and their awareness of mitigation strategies, a detailed interview schedule (APPENDIX –I) was developed with the guidance of experts. This schedule underwent pre-testing, modifications, and standardization based on the feedback gathered in the pilot survey. The responses were collected on a five-point scale, with scores ranging from one to five. The interview schedule was divided into two main parts. The first part aimed to gather basic details of the respondents, such as their age, gender, occupation, and locality. The second part focused on understanding the respondents' knowledge and perception of climate change and the strategies they knew about to mitigate its impact.

3.5.3. Statistical interpretation tools

The data were tabulated on MS-Excel sheet and the individual analysis was carried out. SPSS 16.0 was used for the following test.

Chi-square test for association

Chi-square test was done to find out the association between the perception of the people (urban residents) on climate change based on their age group and gender.

4 RESULTS

4.1 LAND USE / LAND COVER MAP OF KANNUR CORPORATION.

Nine LULC classes were delineated in the LULC map of Kannur Corporation using ArcGIS 10.5 software (Fig.3). They were Urban_compact, Urban_sparse, Urban_vegetated, Industrial, Fallow land, Plantation, Scrubland, Cropland_paddy, and Waterbody. The three major LULC class in Kannur Corporation were Urban_compact, Urban_sparse, Urban_vegetated.

From the prepared map, the area of each urban class was calculated. Among the nine LULC seen in Kannur Corporation, urban_sparse constituted the largest area (44.56%) followed by cropland_paddy (18.96%), fallow land (14.69%), scrubland (9.94%), urban_vegetated (5.13%) and plantation (3.07%). Urban_compact which is the built-up region of the corporation comprises 2.69% of the geographical area of Kannur corporation. Waterbody account for 0.76% of the total area. The least area constituted by LULC class industrial was 0.2% (Fig.2).

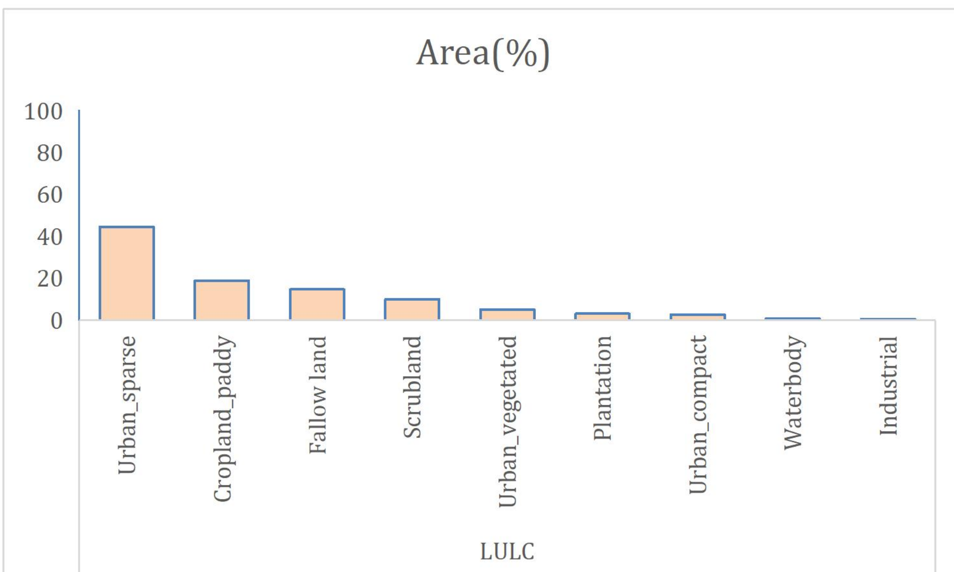

Fig.2: LULC – Area (%) graph of Kannur Corporation

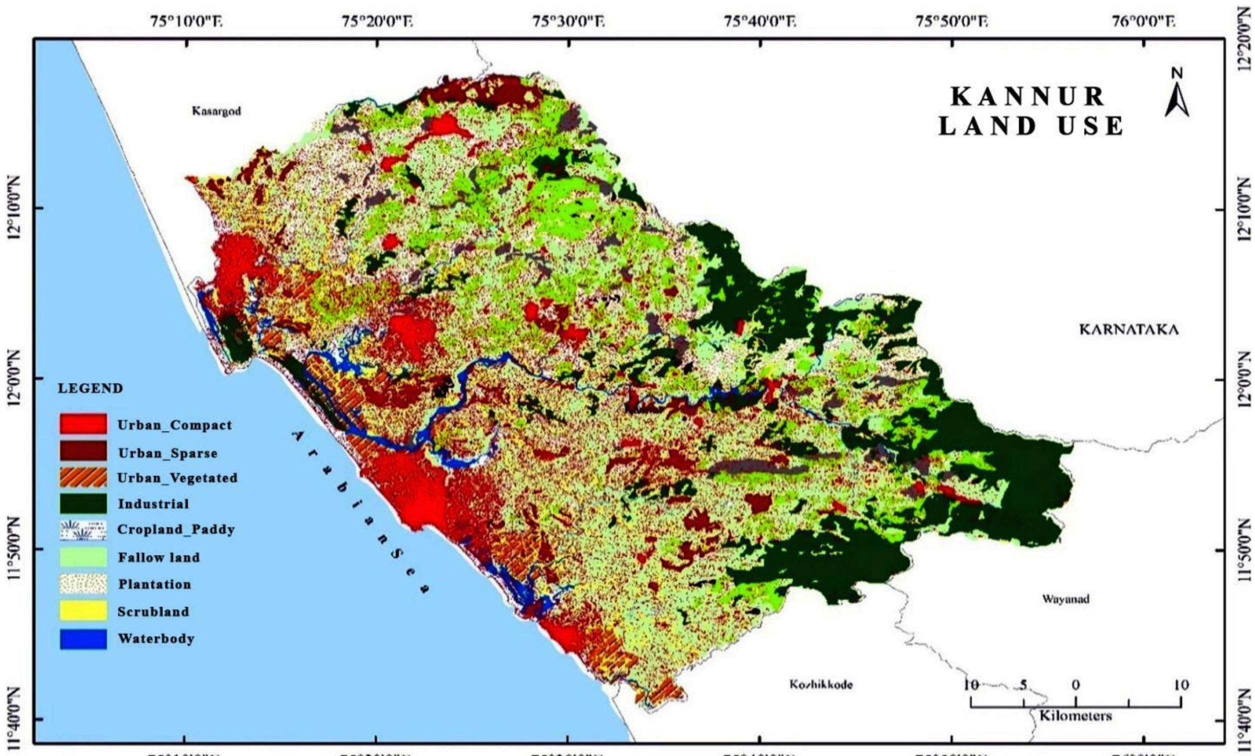

Fig.3: LULC Map of Kannur Corporation

4.2 MICROCLIMATE VARIATION IN DIFFERENT URBAN LULC CLASSES

In order to get the detailed overview of urban microclimate in Kannur corporation, ambient air temperature and relative humidity from three important LULC classes viz urban_compact, urban_sparse, urban_vegetated was measured from January 2023 to March 2023. APPENDIX -II shows the measured air temperature and relative humidity in seven sites from three urban classes that are grouped as per the LULC class. Data collected from seven urban sites were analyzed in terms of the distribution of temperature and relative humidity in each urban class.

4.2.1 Comparison of air temperature in different urban LULC classes in Kannur Corporation

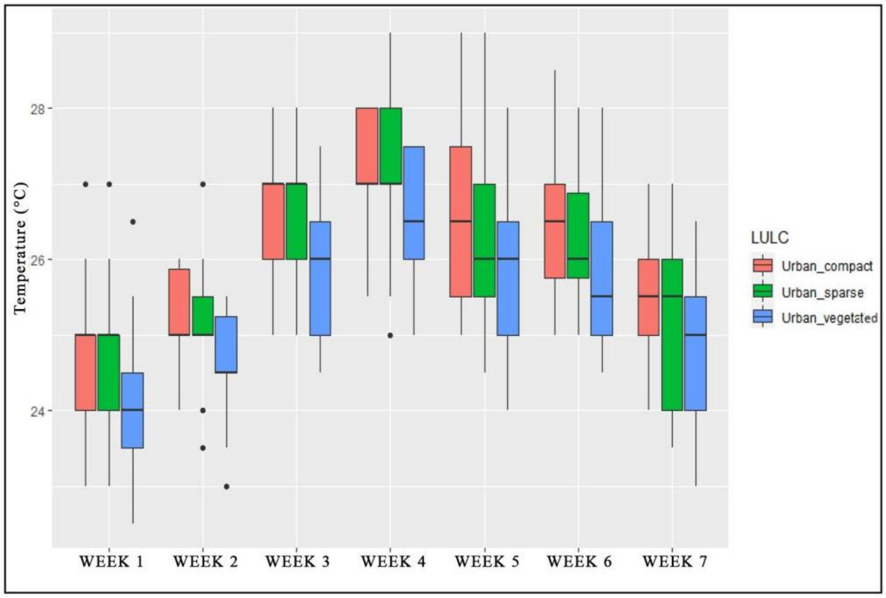

Fig.4: Comparison of air temperature in different LULC class

The highest air temperature recorded during the study period was 29°C during March from LULC classes urban _compact and urban_sparse and the least temperature recorded was 22.5°C in January from LULC urban_vegetated.

During the study period, the highest air temperature in each month was observed from LULC classes urban_compact and urban_sparse. In January, the highest temperature recorded was 26°C from LULC classes urban_compact and urban_sparse. In February, the highest temperature was observed from urban_sparse (27°C). In March, 28°C was the highest temperature observed and that was from LULC classes, urban_compact and urban_sparse.

During the study period in all months, the lowest temperature was observed from LULC urban_vegetated. The lowest temperature observed in January was 22.5°C and it increased to 23°C in February. In March, 24.5°C was the lowest temperature recorded.

During the study period, the low-temperature values in all three LULC classes were observed in January.

4.2.2 Comparison of mean monthly Relative Humidity

During the study period in all months, the highest relative humidity was measured from urban_vegetated. The highest relative humidity in each class during the study period was observed in March, it was 89.41% in urban_vegetated, 88.83% in urban_sparse and 87.46% in urban_compact. The lowest humidity in each class was observed during February and it was 56.53% in urban_vegetated, 52.72% in urban_sparse and 55.71% in urban_compact.

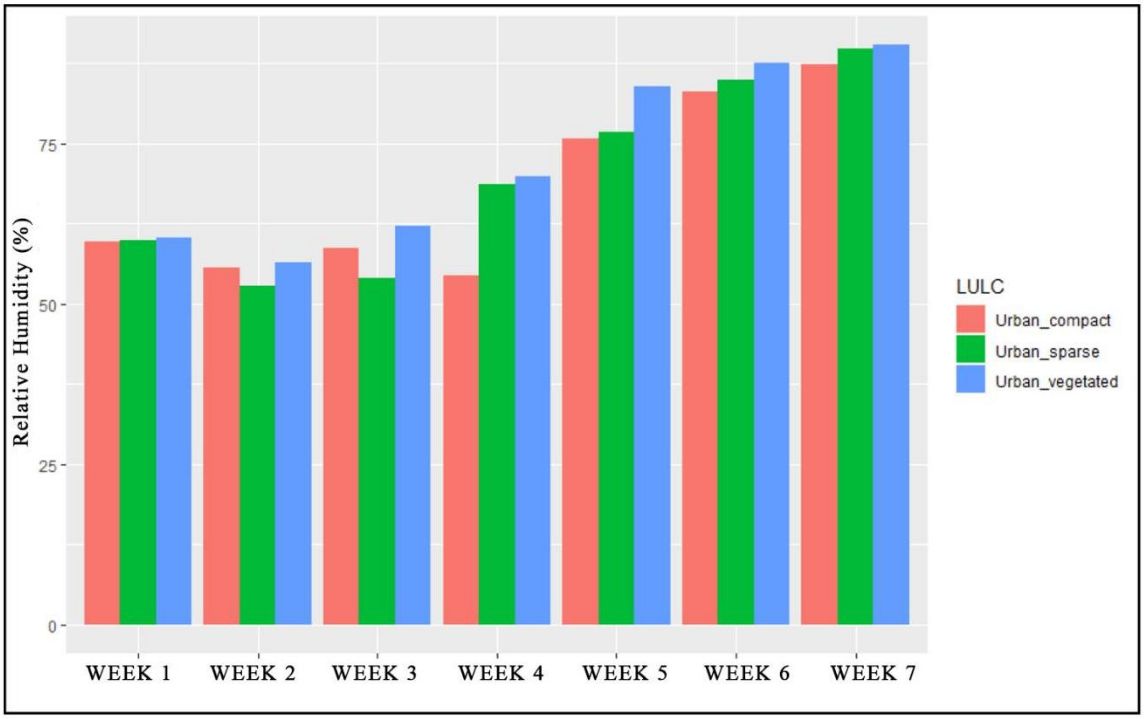

Fig.5: Weekly mean relative humidity during the study

4.3 URBAN-RURAL TEMPERATURE VARIATION

To analyze the urban heat island, the air temperature measured from urban classes was compared with the air temperature from the immediate rural location. The ambient air temperature observed from the rural location was used as a reference point for the estimation of UHI.

The temperature from the seven sites under three LULC classes in the urban area was compared with the temperature measurements from the rural location. The difference in temperature between the urban sites and rural sites was grouped as per the LULC category.

Below illustration (Fig.6) represents the temperature difference between the three urban classes with the rural site. A difference of more than zero was observed in temperature between urban_compact and rural sites. Whereas the difference in temperature between the other two urban classes was not consistent

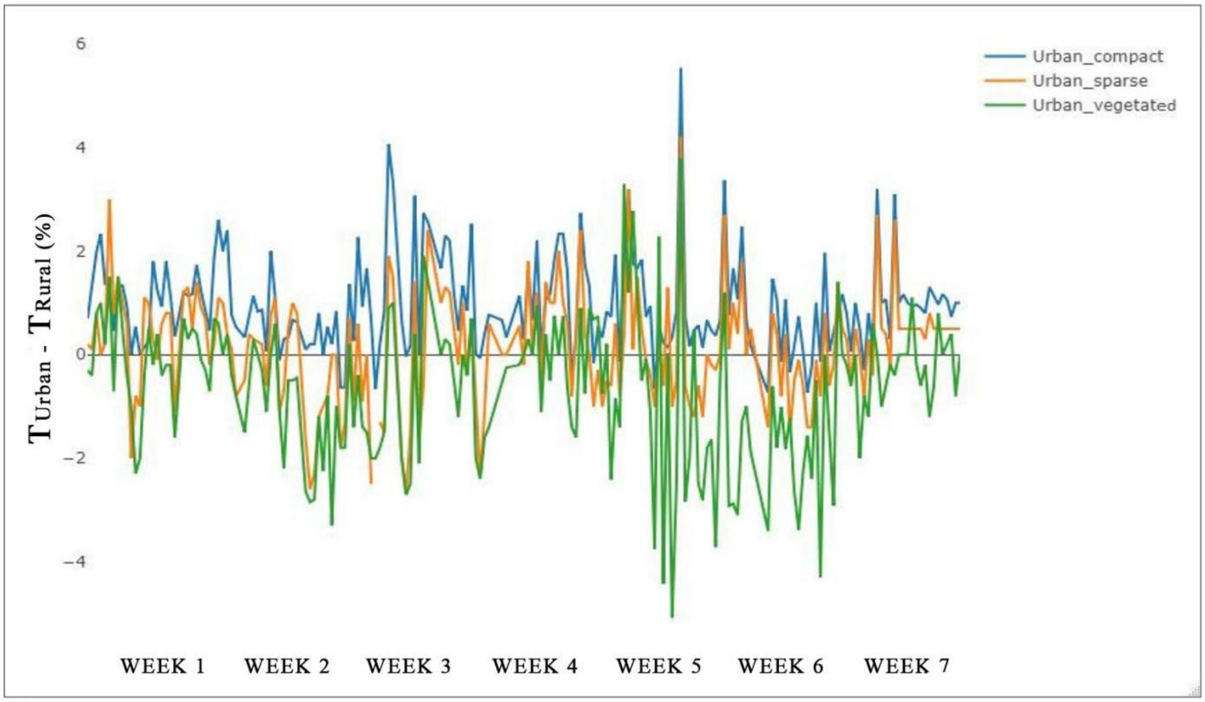

Fig.6: Urban- Rural temperature difference

4.4 URBAN HEAT ISLAND

The air temperature measured from each urban classes such as urban_compact, urban_sparse, urban_vegetated was compared with the rural site to find out the UHI. The difference in the air temperature between the rural site and with each urban class was analysed (Fig.6). From that, it was observed that the urban heat island had developed under the LULC class urban_compact that occupy 2% of the geographical area of Kannur corporation and it is the "heart of the city".

Fig.8 represents the UHI experienced in Kannur from January 2023 to March 2023. In the morning, the highest UHI recorded was 3.1°C in April, followed by 3°C in March. The maximum UHI experienced during January and February are 2.6°C and 2.4°C respectively. There are some days where the UHI dropped below zero.

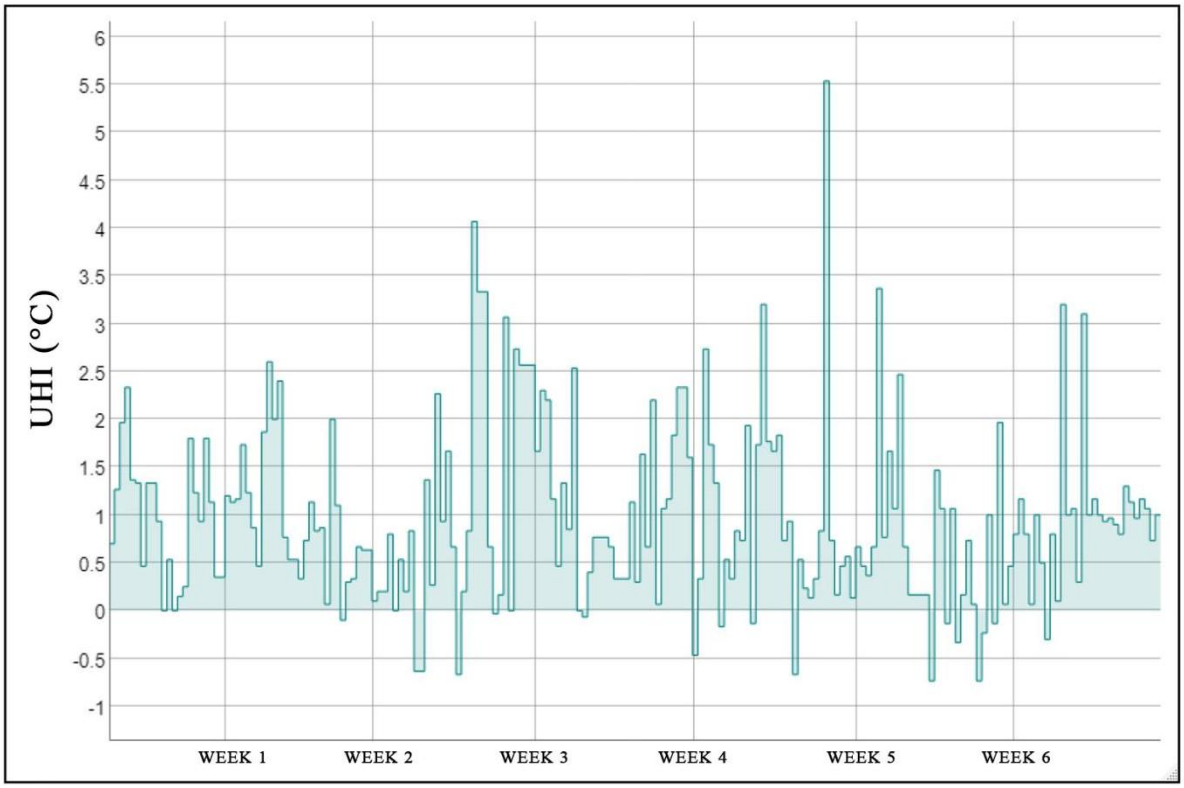

Fig.7: UHI observed

4.5 PERCEPTION SURVEY DONE IN KANNUR CORPORATION

The result of perception study conducted among the urban residents of Kannur corporation is presented below.

4.5.1 Age class of the respondents participated in the survey

Table.3 shows that 56.67 percent of the respondents were belonging to the age class 30-50 years, followed by >50 years (30%) and 13.33 percent by the age class for less than 30 years.

Age	No. of respondents	Percentage
<30 years	4	13.33
30-50 years	17	56.67
>50years	9	30
Total	30	100

Table.3: Age class of the respondents

4.5.2 Perception of respondents on climate change

All the participants in the survey are aware of the climate change happening. Out of total respondents, 80 percent had the opinion that climate change is occurring due to human activities and 20 percent of the respondents are not sure of the cause of climate change.

4.5.3 Opinion of the respondents on the changes happening due to climate change

Sixty percent of respondents strongly agreed that the rising temperature and drought are the major effects of climate change. About 33.33% strongly agreed that the occurring of flood is also due to climate change and 40% agreed for the same. Only 16.67 % people strongly agreed that the sea level change and melting glaciers are happening due to climate change. About 13.33% and 16.67% disagree that the desertification and emerging new diseases are not due to the effects of climate change. About 53.3% of the respondents have the opinion that the reduction in food production is one of the problems caused by climate change.

Probability percentage of each factor was estimated. Majority of the respondents have the opinion that rising temperature (12.4) followed by drought (12.06) (Fig.8) are the most probable climate change manifestation in the environment, whereas glacier melting and emergence of new disease are least effected by climate change.

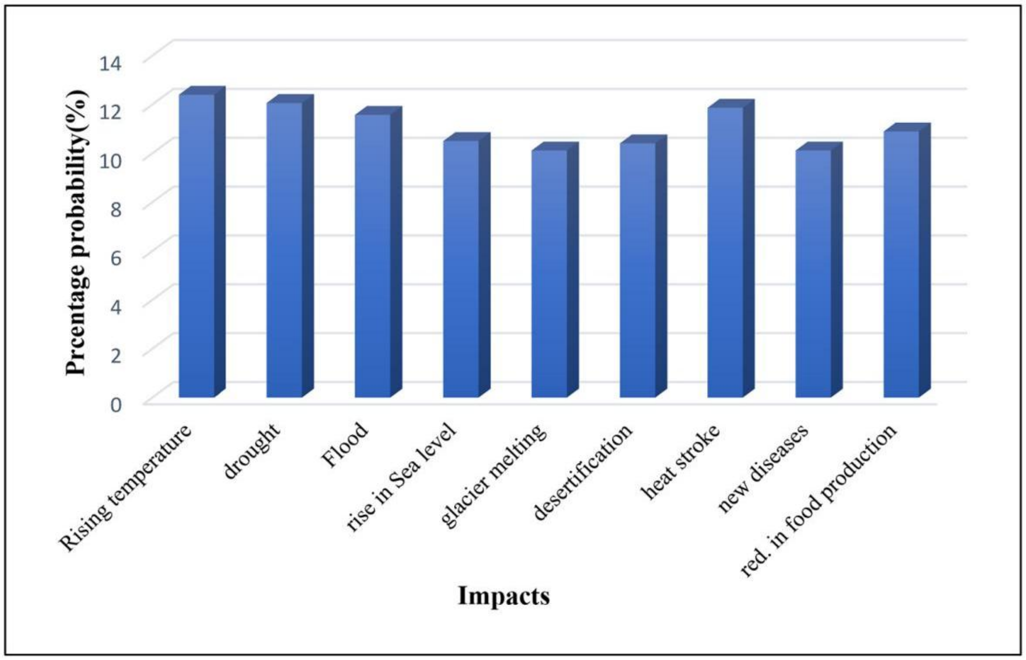

Fig.8: Probability percentage of respondent's opinion on the changes happening due to climate change

4.5.4 Opinion of the respondents on the factors causing climate change

About 96.67% approve with the factor that deforestation is a major cause of climate change. Out of all respondents 60% agreed that the industrialization has contributed to global climate change. About 40% of the respondents do not agree with the natural causes as one of the factors resulting in climate change. Around 17% respondents disagree with fossil fuel emission from automobiles as a reason for climate change.

Probability percentage of each factors causing climate change was estimated. According to respondents' perception, deforestation is the major cause of climate change (29.44%) followed by industrialization (25.40%)

Table.4: Perception on factors causing climate change

	S1		S2		S3		S4	
	N	%	N	%	N	%	N	%
Strongly agree	12	40	5	16.7	2	6.7	6	20
Agree	17	56.7	18	60	10	33.3	18	53.3
Neutral	1	3.3	2	6.7	6	20	3	10
Disagree			5	16.7	11	36.7	5	16.7
Strongly disagree					1	3.3		

S1: Deforestation

S2: Industrialization

S3:Natural causes

S4: Fossil fuel emission from automobiles

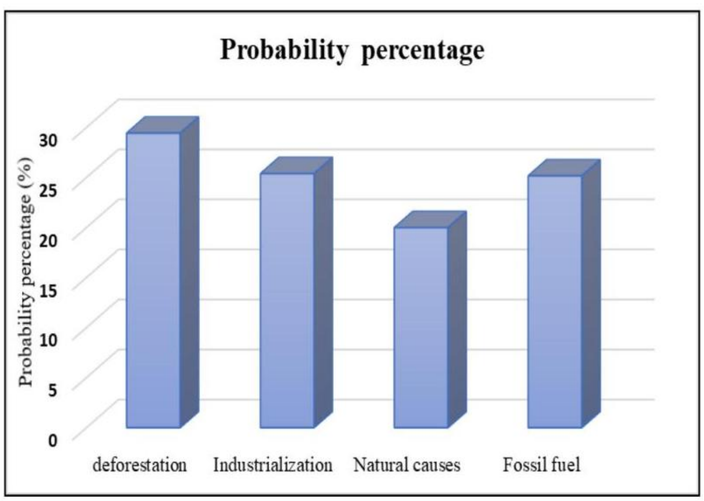

Fig.9: Probability percentage of respondent's opinion on the factors causing climate change

Table.5: Perception of respondents on impacts of climate change

	S1		S2		S3		S4		S5		S6		S7		S8	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Strongly agree	18	60	18	60	10	33.3	5	16.7	5	16.7	5	16.7	4	13.3	4	13.3
Agree	10	33.3	8	26.7	12	40	11	36.7	11	36.7	11	36.7	11	36.7	15	50
Neutral	2	6.7	4	13.3	8	26.7	11	36.7	9	30	10	33.3	10	33.3	10	33.3
Disagree							3	10	5	16.7	4	13.3	5	16.7	1	3.3
Strongly disagree																

S1: Rising temperature

S2: Drought

S3: Flood

S4: Sea level rising

S5: Melting glaciers

S6: Desertification

S7: Emerging new diseases

S8: Reduction in food production

4.5.5 Opinion of the urban residents on the possible health risks due to climate change

About 76.67 percent of the people are aware of the health risks caused due to climate change. Out of all respondents most people approved (96.67%) with the heat stroke as one of the major health risks of climate change followed by sunburn (90%). The health risk that most people disapproved as caused by climate change is cancer (36.67%). The percentage of respondents who agree with the infectious diseases and respiratory problems is 60% and 53.33% respectively. About 43.33% people also agree with allergy as a health risk that may escalate due to climate change.

Table.6: Opinion of the urban residents on the possible health risks due to climate change

	S1		S2		S3		S4		S5		S6	
	N	%	N	%	N	%	N	%	N	%	N	%
Strongly agree	4	13.3	3	10	11	36.7	6	20	10	33.3	6	20
Agree	14	46.7	8	26.7	18	60	10	33.3	17	56.7	7	23.3
Neutral	6	20	8	26.7	1	3.3	11	36.7	2	6.7	9	30
Disagree	5	16.7	9	30			1	3.3	1	3.3	6	20
Strongly disagree	1	3.3	2	6.7			2	6.7			2	6.7

S1: Infectious diseases

S2: Cancer

S3: Heat stroke

S4: Respiratory diseases

S5: Sunburn

S6: Allergy

The highest probability percentage was estimated for heat stroke (19.75) followed by sunburn (19.15). According to respondents' perception heat stroke and sunburn are the predominant health risks due to climate change. Least probability percentage was estimated for cancer (13.8). Most of the respondents don't agree with the cancer as a climate change caused health risk .

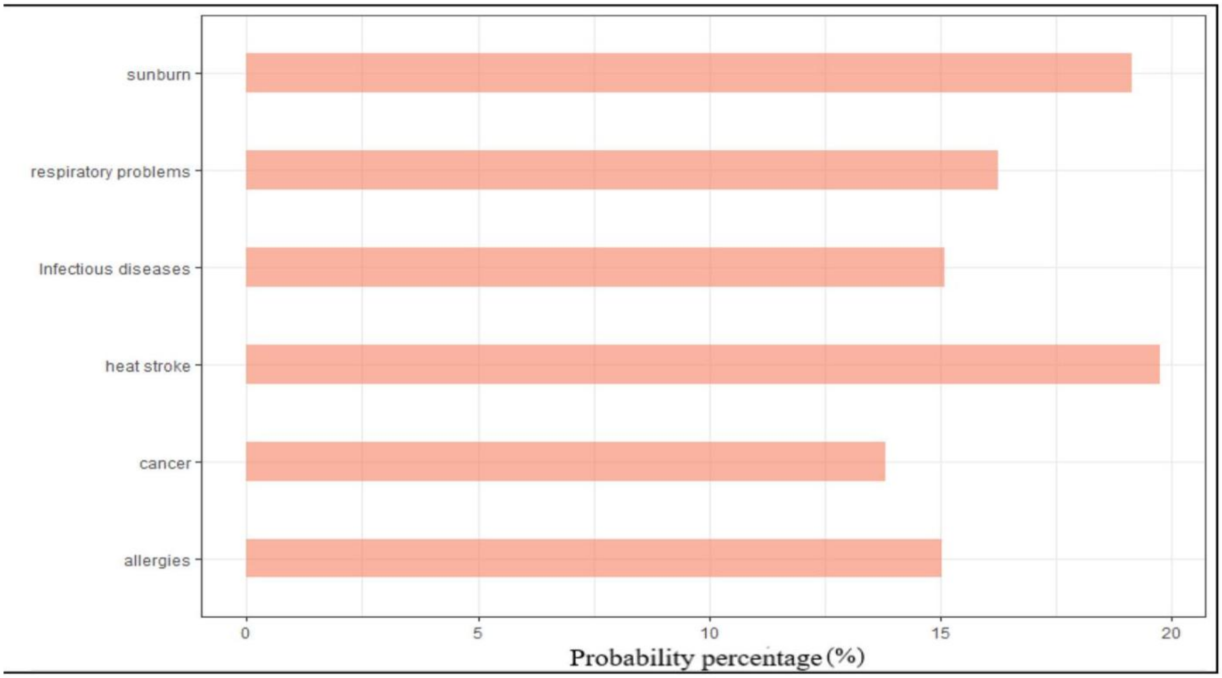

Fig.10: Probability percentage of opinion of the urban residents on the possible health risks due to climate change

4.5.6 Opinion of the urban residents on Urban Heat Island.

Out of total respondents only 16.67 percent people are aware of the phenomena of urban heat island. After explaining the phenomena Urban Heat Island and were asked their view on the possible reasons of increased temperature in the urban center, the following results were obtained. The greatest number of respondents agree that the lack of greenery is one of the major causes of urban heat island (90%) followed by emission of fossil fuel (63.33%). Sixty per cent of respondents also believe that high population density in the urban area has contributed to UHI (Table.7). Whereas about 53.33% of the respondents do not have any response to the factor form and layout of the city as well as the type of construction materials used. When the probability percent of each factor was estimated, respondents have the opinion that lack of greenery (23.10%) followed by fossil fuel emission (21.23%) and population (20.67%) are the predominant causes of UHI (Fig.11)

Table.7: Opinion of the urban residents on Urban Heat Island

	S1		S2		S3		S4		S5	
	N	%	N	%	N	%	N	%	N	%
Strongly agree	6	20	2	6.6	8	26.6	2	6.7	5	16.7
Agree	13	43.3	7	23.3	19	63.3	16	20	13	43.3
Neutral	10	33.3	16	53.3	2	6.7	5	53.3	10	33.3
Disagree	1	3.3	4	13.3	1	3.3	1	16.7	2	6.7
Strongly disagree			1	3.3			1	3.3		

S1: Emission of fossil fuel

S2: Type of construction materials used

S3: Lack of greenery

S4: Form and layout of the city

S5: High population density

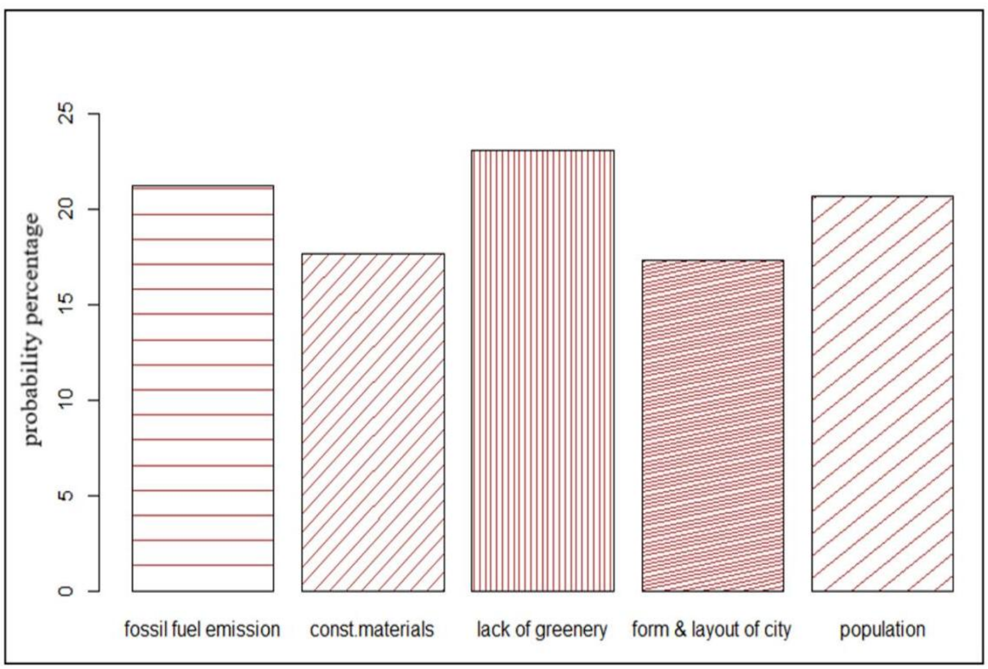

Fig.11: Probability percentage of opinion of the urban residents on urban heat island

4.5.7 Opinion of the residents on possible intervention to reduce UHI

All the respondents were of the opinion that the urban parks are possible solution for the reduction of UHI in the cities. Out of total respondents 54% of the respondents supported the view that green building and green roof can also be adopted as a mitigation method, followed by green pavements, which were supported by 44% of respondents (Table.8). 13% of the respondents disagreed with reducing use of AC as a mitigation measure, while 40% remained neutral. Highest probability percentage was observed for urban parks, followed by green roof and green buildings

	S1		**S2**		**S3**		**S4**		**S5**		**S6**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Strongly agree	12	40	6	20	6	20	6	20	3	10	3	10
Agree	18	60	16	53.3	13	43.3	16	53.3	11	36.7	15	50
Neutral	5	16.7	8	26.7	5	16.7	12	40	9	30		
Disagree			3	10	3	10	3	10	3	10	3	10
Strongly disagree									1	3.3		

Table.8: Opinion of the residents on possible intervention to reduce UHI

S1: Urban parks

S2: Green buildings

S3: Green pavements

S4: Green roofs

S5: Reducing use of AC

S6: Efficient public transport system

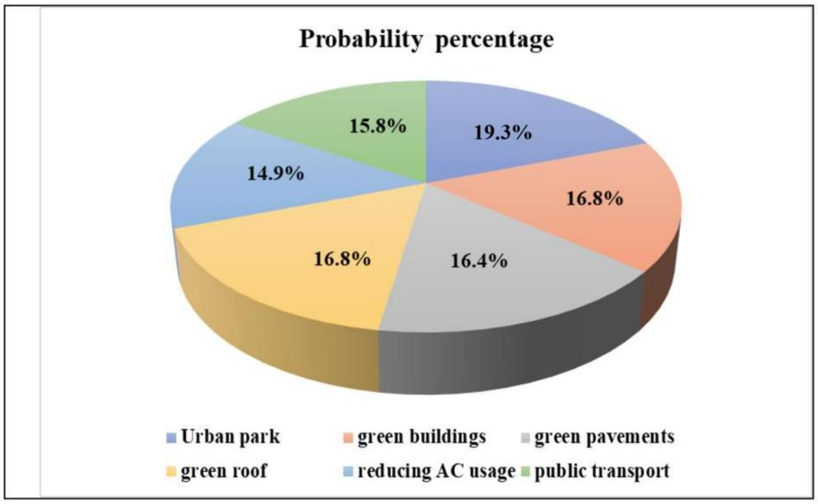

Fig.12: Probability percentage of the opinion of the residents on possible intervention to reduce UHI

4.5.8 Opinion of the residents on the responsibility of tackling climate change.

About 80% of the respondents agreed that the responsibility to tackle climate change is vested primarily on the individual (Table.9). They also agreed that the national and local self-governments also share the same responsibility as individuals. About 76% agreed that the industries and business firms were also responsible for tackling climate change.

	S1		S2		S3		S4		S5		S6	
	N	%	N	%	N	%	N	%	N	%	N	%
Strongly agree	3	10	6	20	6	20	6	20	3	10	9	30
Agree	14	46.7	18	60	18	60	17	56.7	14	46.7	15	50
Neutral	9	30	5	16.7	5	16.7	6	20	9	30	5	16.6
Disagree	4	13.3	1	3.3	1	3.33	1	3.3	1	13.3	1	3.3
Strongly disagree												

Table.9:Opinion of the residents on the responsibility of tackling climate change

S1: International organisations (e.g., UN)

S2: National government

S3: Local government

S4: Industries and business

S5: Environmental organisation

S6: Individual

4.5.9. Response of the people on the methods they are willing to adopt to tackle climate change

About 89% of the people are willing to plant trees for reducing climate change and 70% are agreed to switch off fans and lights if not in use. Only 33% are ready to use public transport system but none agreed to cycle or walk to work.

Table.10: Responds of the people on the methods they are willing to adopt to tackle climate change

	S1		S2		S3		S4		S5		S6	
	N	%	N	%	N	%	N	%	N	%	N	%
Strongly agree	11	36.7	0	0	3	10	0	0	0	0	9	30
Agree	16	53.3	10	33.3	20	66.7	3	10	3	10	13	43.3
Neutral	3	10	13	43.3	6	20	7	23.3	7	23.3	8	26.7
Disagree			7	23.3	1	3.3	20	66.7	20	66.7		
Strongly disagree												

S1: Planting trees

S2: Use of public transportation

S3: Use of energy efficient gadgets

S4: Walk to work

S5: Cycle to work

S6: Switch off fans and lights not in use

The probability percentage of respondent's willingness to plant trees to tackle climate change was highest (22.90%) and they were willing to reduce the use of electricity for the mitigation of climate change (Fig.13). But the respondents are not willing to cycling and walking to their work place as it is not a convenient for them.

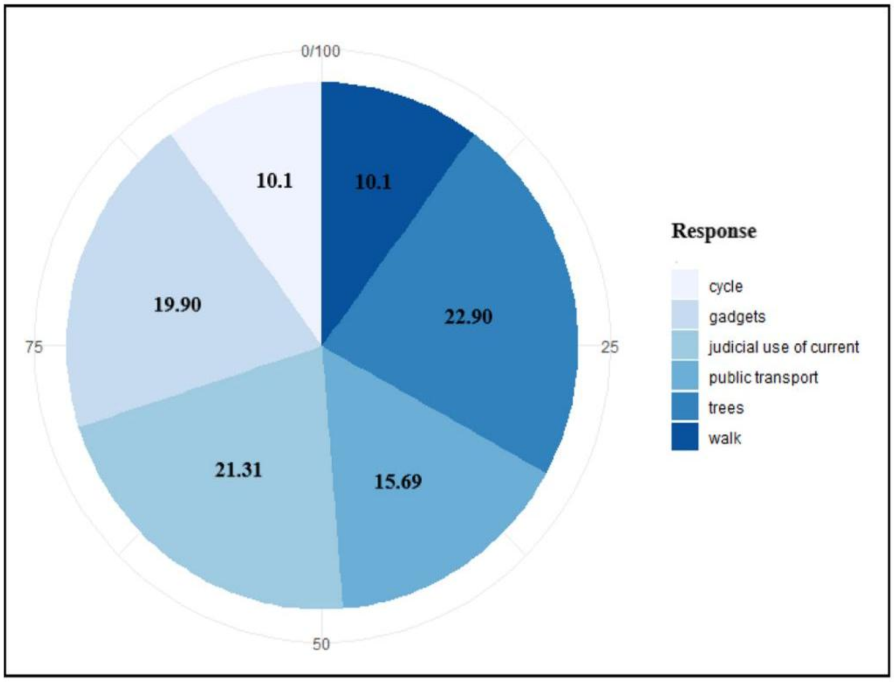

Fig.13: Probability percentage of response of the people on the methods they are willing to adopt to tackle climate change

5. SUMMARY

The study entitled "Analysis of Urban Microclimate in Kannur Corporation using micrometeorological measurements and remote sensing data" was undertaken to analyse the urban microclimate of Kannur corporation and the development of Urban Heat Island in the city. The study also investigated the perception of urban dwellers on climate change. The results obtained from this study are summarized in this chapter.

1. Kannur Municipal Corporation is comprised of nine different Land Use Land Cover classes, namely,urban_compact, urban_sparse, urban_vegetation, cropland_paddy, Fallow land, scrubland, waterbody,plantation and industrial. The LULC class urban_sparse accounts for highest area (63%). The major three urban classes are urban_compact, urban_sparse and urban_vegetation..
2. The ambient air temperature was observed to be similar in urban classes, namely- urban_compact and urban_sparse, whereas there is subtle difference in the morning air temperature in LULC urban_vegetation.
3. The highest air temperature was observed in urban_compact followed by urban_sparse. The lowest air temperature was observed in urban_vegetation.
4. The mean monthly relative humidity was observed to be high in urban_vegetation followed by urban_sparse.
5. The temperature difference between rural area and three urban classes were assessed. Urban heat island intensity in the range 0 ºC -5.5ºC was observed to be developed in the LULC class urban_compact.
6. The most frequently observed UHI intensity fall within the range 1-1.2°C followed by 0.8°C-1.0°C
7. The causes of climate change as understood by the respondents are mainly deforestation and fossil fuel emission. About 80 per cent of the respondents believes that humans have a major role in causing climate change.
8. The impacts of climate change as noticed by the respondents included increase in temperature and drought. Flood, emerging new diseases, decreasing food production

through yield loss and increasing risk of heat strokes were also reported as the impacts of climate change by the people.

REFERENCES

Agrawal, M., Singh, B., Agrawal, S.B., Bell, J.N.B., and Marshall, F. 2006. The effect of air pollution on yield and quality of mung bean grown in peri-urban areas of Varanasi. Water, Air, and Soil Pollut. 169(1): 239-254.

Akbari, H., Pomerantz, M., and 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.

Alonso, M.S., Fidalgo, M.R., and Labajo, J.L. 2007. The urban heat island in Salamanca (Spain) and its relationship to meteorological parameters. Clim. Res. 34(1):39- 46.

Ampatzidis, P. and Kershaw, T. 2020. A review of the impact of blue space on the urban microclimate. Sci. Total Environ.730:139068.

Anderson, G.B. and Bell, M.L. 2011. Heatwaves in the United States: mortality risk during heat waves and effect modification by heat wave characteristics in 43 US communities. Environ. Health Perspect.119(2): 210-218.

Ansar, S., Dhanya, C.R., Thomas, G., Chandran, A., John, L., Prasanthi, S., Vishnu, R.,and Zachariah, E.J. 2012. A study of urban/rural cooling rates in Thiruvananthapuram, Kerala. Journal of Indian Geophysical. Union 16(1):29-36.

Arifwidodo, S.D. and Tanaka, T. 2015. The characteristics of urban heat island in Bangkok, Thailand. Procedia Social and Behavioural. Science 195: 423-428.

Arnfield, A.J. 2003. Two decades of urban climate research: a review of turbulence, ex- changes of energy and water, and the urban heat island. Int. J. Climatol. 23: 1–26.

Arulbalaji, P., Padmalal, D., and Maya, K. 2020. Impact of urbanization and land surface temperature changes in a coastal town in Kerala, India. Environ. Earth Sci. 79(17): 1-18. ii

Ashie, Y., Thanh, V. C., and Asaeda, T.1999. Building canopy model for the analysis of urban climate. J. Wind Eng. Ind. Aerodyn. 81: 237–248.

Avdan, U. and Jovanovska, G. 2016. Algorithm for automated mapping of land surface temperature using LANDSAT 8 satellite data. J. Sens.

Baker, L.A., Brazel, A.J., Selover, N., Martin, C., McIntyre, N., Steiner, F.R., Nelson, A., and Musacchio, L. 2002. Urbanization and warming of Phoenix (Arizona, USA): Impacts, feedbacks and mitigation. Urban Ecosyst. 6(3):183-203.

Bokaie, M., Zarkesh, M.K., Arasteh, P.D., and Hosseini, A. 2016. Assessment of urban heat island based on the relationship between land surface temperature and land use/land cover in Tehran. Sustain. Cities and Soc. 23: 94-104.

Bourbia, F. and Boucheriba, F. 2010. Impact of street design on urban microclimate for semi-arid climate (Constantine). Renewable Eng. 35(2): 343-347.

Buyadi, S.N.A., Mohd, W.M.N.W., and Misni, A. 2015. Vegetation's role on modifying microclimate of urban resident. Procedia-Social and Behav. Sci. 202: 400-407.

Ca, V.T., Asaeda, T., Abu, E. M. 1998. Reductions in air-conditioning energy caused by a nearby park. Eng. and Build. 29: 83–92.

Camuffo, D. 1998. Microclimate for cultural heritage (3rd Ed.). Candice Janco publisher.

Cao, C., Lee, X., Liu, S., Schultz, N., Xiao, W., Zhang, M., and Zhao, L. 2016. Urban heat islands in China enhanced by haze pollution. Nat. commum. 7(1): 1-7.

Chan, S.Y., Chau, C.K., Leung, T.M. 2017. On the study of thermal comfort and perceptions of environmental features in urban parks: a structural equation modelling approach. Build. Environ. 122: 171–183

Chen, L., Ng, E., An, X., Ren, C., Lee, M., Wang, U., and He, Z. 2010. Sky view factor analysis of street canyons and its implications for daytime intra-urban air temperature differentials in high-rise, high-density urban areas of Hong Kong: a GIS-based simulation approach. Int. J. Climatol. 32(1): 121–136. iii

Chow, W.T. and Roth, M. 2006. Temporal dynamics of the urban heat island of Singapore. Int. J. Climatol.: J. R. Meteorol Soc. 26(15): 2243-2260.

Chun, B. and Guldmann, J. M. 2014. Spatial statistical analysis and simulation of the urban heat island in high-density central cities. Landsc. Urban Plan. 125 (3): 76-88

Davis, K. 1965. The urbanization of the human population. Sci. Am. 213(3): 40-53.

Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G., and Spence, A. 2017. Experience of extreme weather affects climate change mitigation and adaptation responses. Climatic Change. 140(2): 149–164.

Devika, K.C., Bhattathiripad, T.R., and Kothari, B.S. 2016. Emerging paradigms for development planning: A case of Thrissur, the cultural capital of Kerala. Proc. Technol. 24: 1681-1690.

DeWitt, J. and Brennan, M. 2001. Taking the heat. Imaging Notes 16(6): 20-23.

Dimoudi, A. and Nikolopoulou, M. 2003. Vegetation in the urban environment: microclimatic analysis and benefits. Eng. Buiild 35(1): 69-76.

Emmanuel, R. 1997. Urban vegetational change as an indicator of demographic trends in cities: the case of Detroit. Environ. Plan.: Plann. Des. 24(3): 415-426.

Fallmann, J., Forkel, R., and Emeis, S. 2016. Secondary effects of urban heat island mitigation measures on air quality. Atmos. Environ. 125: 199-211.

Gaitani, N., Spanou, A., Saliari, M., Synnefa, A., Vassilakopoulou, K., Papadopoulou, K., Pavlou, K., Santamouris, M., Papaioannou, M. and Lagoudaki, A. 2011. iv Improving the microclimate in urban areas: a case study in the centre of Athens. Building Services Engineering Research and Technology. 32(1): 53-71.

Givoni, B.1998. Climate Considerations in Building and Urban Design, Thomson, New York, Grimmond, S.U.E. 2007. Urbanization and global environmental change: local effects of urban warming. The Geographical Journal 173(1): 83-88.

Grover, A. and Singh, R.B. 2015. Analysis of urban heat island (UHI) in relation to normalized difference vegetation index (NDVI): A comparative study of Delhi and Mumbai. Environ. 2(2): 125-138.

Gunawardena, K.R., Wells, M.J. and Kershaw, T. 2017. Utilising green and blue space to mitigate urban heat island intensity. Sci. Total Environ. 584: 1040-1055.

Haque, I. and Patel, P.P. 2018. Growth of metro cities in India: trends, patterns and determinants. Urban Res. Pract. 11(4): 338-377.

Hassid, S., Santamouris, M.N.A.N.C., Papanikolaou, N., Linardi, A., Klitsikas, N., Georgakis, C. and Assimakopoulos, D.N. 2000. The effect of the Athens heat island on air conditioning load. Energy Build. 32(2):131-141.

He, B.J., Zhao, Z.Q., Shen, L.D., Wang, H.B., Li, L.G. 2019. An approach to examining performances of cool/hot sources in mitigating/enhancing land surface temperature under different temperature backgrounds based on Landsat 8 image. Sustain. Cities Soc. 44: 416–427.

He, C., Liu, Z., Gou, S., Zhang, Q., Zhang, J., and Xu, L., 2019. Detecting global urban expansion over the last three decades using a fully convolutional network. Environ. Res. Lett. 14(3): 34008v

Huang, B., Zhao, B., and Song, Y. 2018. Urban land-use mapping using a deep convolutional neural network with high spatial resolution multispectral remote sensing imagery. Remote Sens. Environ. 214: 73-86.

Jain, M. and Pathak, K.K. 2019. Effect of Urban Morphology on Subtropical Humid Microclimate: The Case of Bhopal, India. Int. J. Recent. Technol. Eng. 10(10)

Jauregui, E. 1991. Influence of a large urban park on temperature and convective precipitation in a tropical city. Eng. Builds. 15(3-4): 457-463.

Jaysawal, D. and Saha, S., 2014. Urbanization in India: An impact assessment. Int J Sociol Soc Policy. 4(2):60-65.

Johansson, E. and Emmanuel, R. 2006. The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. Int J Biometeorol. 51(2): 119-133. vi

Kikegawa, Y., Genchi, Y., Yoshikado, H. and Kondo, H. 2003. Development of a numerical simulation system toward comprehensive assessments of urban warming countermeasures including their impacts upon the urban buildings, energy demands. Appl.Eng. 76: 449–466

Kim, Y.H. and Baik, J.J. 2002. Maximum urban heat island intensity in Seoul. J. Appl. Meteoro. 41(6): 651-659

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., and Hyatt, O. 2016. Heat, human performance, and occupational health: a key issue for the assessment of global climate change impacts. Annual review of public health 37: 97-112.

Kleerekoper, L., van Esch, M., Salcedo, T.B. 2012. How to make a city climate-proof, ad- dressing the urban heat island effect. Resour. Conserv. Recycl. 64: 30–38

Kłysik, K. and Fortuniak, K. 1999. Temporal and spatial characteristics of the urban heat island of Łódź, Poland. Atmos. Environ. 33(24-25): 3885-3895.

Kolokotroni, M., Ren, X., Davies, M. and Mavrogianni, A. 2012. London's urban heat island: Impact on current and future energy consumption in office buildings. Energy Build. 47: 302–311.vii

Kondoh, A. and Nishiyama, J. 1999. Changes in hydrological cycle due to urbanization in the suburb of Tokyo Metropolitan Area, Japan. Adv. Space Res. 26: 1173– 1176.

Kumar, K.S., Bhaskar, P.U., and Padmakumari, K. 2012. Estimation of land surface temperature to study urban heat island effect using Landsat ETM+ image. Int. J. Eng. Sci. Technol. 4(2): 771-778.

Kundu and Basu, S. 1998. Informal Manufacturing Sector in Urban Areas– An Analysis of Recent Trends. Int. J. Manpow. 34(1).

Lakshmana, C.M. 2013. Population, development, and environment in India. Chinese J. Popul. Resour. Environ. 11(4): 367–374.

Lal, P. and Nair, S.B. 2017. Urbanization in Kerala—What Does the Census Data Reveal? Indian Journal of Human Development, 11(3): 356-386.

Lee, J.S., Kim, J.T. and Lee, M.G. 2014. Mitigation of urban heat island effect and greenroofs. Indoor and Built Environment. 23(1): 62-69.

Li, J., Wang, Y., Ni, Z., Chen, S. and Xia, B. 2020. An integrated strategy to improve the microclimate regulation of green-blue-grey infrastructures in specific urban forms. J. Clean. Prod. 271: 122555.

Macbeth, H. and Collinson, P. eds., 2002. Human population dynamics: crossdisciplinary perspectives (Vol. 14). Cambridge University Press.

Mahmoud, A.H.A. 2011. Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions. Build. Environ. 46(12): 2641-2656.

Makvandi, M., Li, B., Elsadek, M., Khodabakhshi, Z. and Ahmadi, M. 2019. The interactive impact of building diversity on the thermal balance and microclimate change under the influence of rapid urbanization. Sustain. 11(6):1662.

Marsh, W. M. and Grossa, J. M. Jr. 2002. Environmental Geography: Science, Land Use, and Earth Systems (2nd Ed.) Wiley and Sons, New York

Mayaja, N.A. and Srinivasa, C.V. 2017. Land use and land cover changes and their impacts in Pampa river basin in Kerala: A remote sensing based analysis. Int.J. Geomat.11(1): 1-6.

Memon, R.A., Leung, D.Y., and Liu, C.H. 2009. An investigation of urban heat island intensity (UHII) as an indicator of urban heating. Atmos. Rese. 94(3): 491-500.

Nelson, K.C., Palmer, M.A., Pizzuto, J.E., Moglen, G.E., Angermeier, P.L., Hilderbrand, R.H., Dettinger, M., and Hayhoe, K. 2009. Forecasting the combined effects of urbanization and climate change on stream ecosystems: From impacts to management options. J. Appl. Ecol. 46: 154–163.

Nichol, J. E. 1994. A GIS-based approach to microclimate monitoring in Singapore's high-rise housing estates. Photogramm. Eng. Remote Sens. 60: 1225 – 1232.

Nijman, J. 2012. India's Urban Challenge..Eurasian. Geogr. Econ. 53(1): 7–20.

Oke, T.R. 1967. City size and the urban heat island. Atmos. Environ. 7: 769–779.

Pandey, A.K., Singh, S., Berwal, S., Kumar, D., Pandey, P., Prakash, A., Lodhi, N., Maithani, S., Jain, V.K., and Kumar, K. 2014. Spatio–temporal variations of urban heat island over Delhi. Urban Clim. 10: 119-133.

Parvathy, S. and Thomas, R. 2021. Impact of urbanization on flooding in chalakudy river. In:IOP Conference Series: Materials Science and Engineering;12-14 March 2021,Korea,p.12025. x Pathirana, A., Denekew, H.B., Veerbeek, W., Zevenbergen, C., and Banda, A.T. 2014. Impact of urban growth-driven landuse change on microclimate and extreme precipitation—A sensitivity study. Atmos. Res. 138: 59-72.

Patz, J. A., Campbell, L.D., Holloway, T. and Foley, J. A. 2005 Impact of regional climate change on human health. Nature. 438(7066): 310–317

Peppes, A.A., Santamouris, M., and Asimakopoulos, D.N. 2001. Buoyancy-driven flow through a stairwell. Build. Environ.36(2): 167-180.

Radhi, H. and Sharples, S. 2013. Quantifying the domestic electricity consumption for air-conditioning due to urban heat islands in hot arid regions. Appl. Energy 112: 371-380

Ramachandra, T.V., Kumar, U. and Dasgupta, A., 2016. Analysis of land surface temperature and rainfall with landscape dynamics in Western Ghats, India. J Indian Inst Sci 181.

Rao, G.P. 2016. Weather extremes and plantation crops in the humid tropics. Weather 631(540): 251-258.

Rizwan, A.M., Dennis, L.Y., and Chunho, L.I.U. 2008. A review on the generation, determination and mitigation of Urban Heat Island. J. Environ. Sci. 20(1): 120- 128.

Rocklov, J., Forsberg, B., Ebi, K. and Bellander, T. 2014. Susceptibility to mortality related to temperature and heat and cold wave duration in the population of Stockholm Country, Sweeden. Glob. Health Action 7 (10)

Rosenfeld, A.H., Akbari, H., Romm, J.J., and Pomerantz, M. 1998. Cool communities: strategies for heat island mitigation and smog reduction. Energy Build.28(1): 51-62.

Rosenzweig, C., Solecki, W., & Slosberg, R. (2006). Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces. A report to the New York State Energy Research and Development Authority. Xi

Sagan, C., Toon, O.B., and Pollack, J.B. 1979. Anthropogenic Albedo changes and the Earth's climate. Sci. 206 (4425): 1363–1368

Sailor, D. J. and Fan, H. 2002. Modeling the diurnal variability of effective albedo for cities. Atmos. Environ. 36(4): 713–725.

Santamouris, M. 2007. Heat island research in Europe: the state of the art. Adv. Build. Energy Res. 1(1): 123-150.

Sarrat, C., Lemonsu, A., Masson, V., and Guedalia, D. 2006. Impact of urban heat island on regional atmospheric pollution. Atmos. Environ. 40(10): 1743-1758.

Seppänen, O.A. and Fisk, W. 2006. Some quantitative relations between indoor environmental quality and work performance or health. Hvac&R Res. 12(4): 957-973.

Sharma, R. and Joshi, P.K. 2014. Identifying seasonal heat islands in urban settings of Delhi (India) using remotely sensed data – An anomaly-based approach. Urban Clim. 9: 19–34.

Shashua-Bar, L. and Hoffman, M.E. 2004. Quantitative evaluation of passive cooling of the UCL microclimate in hot regions in summer, case study: urban streets and courtyards with trees. Build. Environ. 39(9): 1087-1099.

Shepherd, J. M., Pierce, H., and Negri, A. J. 2002. Rainfall modification by major urban areas: Observation from spaceborne rain radar on the TRMM satellite. J. Appl. Meteorl. 41: 689–701 xii

Shickman, K. and Alliance, G.C.C. 2014. Cool Policies for Cool Cities: Best Practices for Mitigating Urban Heat Islands in North American Cities. ACEEE Summer Study Energy Effic. Build.1-53.

Simmons, M.T., Gardiner, B., Windhager, S., and Tinsley. J. 2008. Green roofs are not created equal: The hydrologic and thermal performance of six different extensive green roofs and reflective and non-reflective roofs in a sub-tropical climate. Urban Ecosyst. 11: 339

Skelhorn, C.P., Levermore, G., and Lindley, S.J. 2016. Impacts on cooling energy consumption due to the UHI and vegetation changes in Manchester,UK. Energy Build. 122: 150-159.

Sobrino, U. and Jovanovska, G. 2016. Algorithm for automated mapping of land
surface temperature using LANDSAT 8 satellite data. J. Sens.

Soltani, A. and Sharifi, E. 2017. Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide. Front. Archit. Res. 6(4): 529-538

Sonu, T.S. and Bhagyanathan, A. 2022. The impact of upstream land use land cover change on downstream flooding: A case of Kuttanad and Meenachil River Basin, Kerala, India. Urban Clim. 41:1089. Spangenberg, J. 2007. Improvement of urban microclimate in tropical metropolis-A case study Maracanã.

Spangenberg, J., Shinzato, P., Johansson, E., and Duarte, D. 2008. Simulation of the influence of vegetation on microclimate and thermal comfort in the city of São Paulo. Revista da Sociedade Brasileira de Arborização Urbana 3(2): 1-19.

Spronken-Smith, R. A., Oke, T. R., and Lowry, W.P., 2000. Advection and the surface energy balance across an irrigated urban park. Int. J. Climatol. 20: 1033–1047.

Stull, R.B. 1988. An Introduction to Boundary Layer Meteorology. Springer Science & Business Media. vol 13. xiii

Sultana, S. and Satyanarayana, A.N.V., 2019. Impact of urbanisation on urban heat island intensity during summer and winter over Indian metropolitan cities. Environmental monitoring and assessment, 191(3):1-17.

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

Thomas, G. and Zachariah, E.J. 2011. Urban heat island in a tropical city interlaced by wetlands. J. Environ. Sci. Eng. 5: 234-240.

Todhunter, P.E.1990. Microclimatic Variations Attributable to Urban Canyon Asymmetry and Orientation‖. Phys. Geogr. 11: 131-141.

Tomita, T., Kusaka, H., Akiyoshi, R., and Imasato, Y. 2007. Thermal and geometric controls on the rate of surface air temperature changes in a medium-sized, midlatitude city. J Appl Meteorol. 46: 241–247

UN Habitat. (2011). Global report on human settlements 2011 cities and climate change. London: Earthscan United Nations, 2018.World Urbanization Prospects,2018 Report. Available:

https://population.un.org/wup/Publicati ons/Files/WUP2018-Report.pdf

Urano, A., Ichinose, T., and Hanaki, K., 1999. Thermal environment simulation for three-dimensional replacement of urban activity.Wind. Eng. Ind. Aerodyn. 81: 197–210. xiv

Vailshery, L.S., Jaganmohan, M., and Nagendra, H. 2013. Effect of street trees on microclimate and air pollution in a tropical city. Urban forestry & urban greening 12(3): 408-415. Vardoulakis, E., Karamanis, D., Fotiadi, A., and Mihalakakou, G. 2013. The urban heat island effect in a small Mediterranean city of high summer temperatures and cooling energy demands. Solar Energy 94: 128–144.

Veena, K., Parammasivam, K.M., and Venkatesh, T.N. 2020. Urban Heat Island studies: Current status in India and a comparison with the international studies. J.Earth Syst. Sci. 129(1): 1-15.

Veettil, B.K. and Grondona, A.E.2018. Vegetation changes and formation of small scale urban heat islands in three populated districts of Kerala State, India. Acta Geophys. 66(5):1063-72.

Völker, S., Baumeister, H., Claben, T., Hornberg, C., and Kistemann, T. 2013. Evidence for the temperature-mitigating capacity of urban blue space – a health geographic perspective. Erdkunde 67: 355–371

Voogt, J. A. and Oke, T. R.: 2003. Thermal remote sensing of urban climate. Remote Sens. Environ. 86, 370–384

Wang, J., Xu, C., Pauleit, S., Kindler, A., and Banzhaf, E. 2019. Spatial patterns of urban green infrastructure for equity: A novel exploration. J. Clean. Prod. 238: 117858.

Waseem, L.A., Khokhar, M.A.H., Naqvi, S.A.A., Hussain, D., Javed, Z.H., and Awan, H.B.H. 2021. Influence of Urban Sprawl on Microclimate of Abbottabad, Pakistan. Land 10(2): 95.

Waseem, S. and Khayyam, U. 2019. Loss of vegetative cover and increased land surface temperature: A case study of Islamabad, Pakistan. J. Clean. Prod. 234: 972-983.

Watson, I.D. and Johnson, G.T., 1987. Graphical estimation of sky view-factors in urban environments. J. Climatol. 7(2): 193-197.

Wei, J., Hansen, A., Zhang, Y., Li, H., Liu, Q., Sun, Y., and Bi, P. 2014. Perception, attitude and behaviour in relation to climate change: a survey among CDC health professionals in Shanxi province, China. Environ. Res. 134: 301-308.

Wei, R., Song, D., Wong, N.H., and Martin, M. 2016. Impact of urban morphology parameters on microclimate. Procedia Eng. 169: 142-149.

Weidong, L., Huanling, Y., and Junxia, D. 2009. Urban-rural humidity and temperature differences in the Beijing area. Theor. Appl. Climatol. 96(3): 201–207.

Weng, Q. 2003. Fractal analysis of satellite-detected urban heat island effect. Photogramm. Eng. Remote Sens.69: 555 – 566

Xu, X., Sun, S., Liu, W., García, E.H., He, L., Cai, Q., Xu, S., Wang, J., and Zhu, J. 2017. The cooling and energy saving effect of landscape design parameters of urban park in summer: A case of Beijing, China. Energy and Buildings 149: 91- 100. xvi

Yang, X., Zhao, L., Bruse, M., and Meng, Q. 2013. Evaluation of a microclimate model for predicting the thermal behavior of different ground surfaces. BuilD. Environ.60: 93-104.

Yao, R., Wang, L., Huang, X., Niu, Y., Chen, Y., and Niu, Z. 2018. The influence of different data and method on estimating the surface urban heat island intensity. Ecol. Indic. 89: 45–55 Yoshikado, H. and Tsuchida, M. 1996. High levels of winter air pollution under the influence of the urban heat island along the shore of Tokyo Bay. J. Appl. Meteorol. Climatol. 35(10): 1804-1813.

Yu, H., Wang, B., Zhang, Y.J., Wang, S., and Wei, Y.M. 2013. Public perception of climate change in China: results from the questionnaire survey. Natural hazards 69(1): 459-472.

Yuan, F. and Bauer, M. E. 2007. Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. Remote Sens. Environt. 106(3): 375–386.

Zander, K.K., Botzen, W.J., Oppermann, E., Kjellstrom, T. and Garnett, S.T. 2015. Heat stress causes substantial labour productivity loss in Australia. Nat. Clim. Change 5(7): 647-651.

Zhao, L., Oppenheimer, M., Zhu, Q., Baldwin, J.W., Ebi, K.L., Bou-Zeid, E., Guan, K., and Liu, X. 2018. Interactions between urban heat islands and heat waves. Environ. Res. Lett. 13(3): 34003.

Zhou, Q., Leng, G., Su, J., and Ren, Y. 2019. Comparison of urbanization and climate change impacts on urban flood volumes: Importance of urban planning and drainage adaptation. Sci. Total Environ. 658: 24-33.

APPENDIX - I

SURVEY ABOUT PERCEPTIONS OF URBAN RESIDENTS ABOUT DIFFERENT ASPECTS OF CLIMATE CHANGE

Part I

Name: Address: Occupation:

Gender: Location:

Age:

Date & Time:

Part II

Gender: Location:

Age:

Date & Time:

1. Are you aware of climate change? Yes/No/Don't know

2.In your opinion, what is the reason for the climate change?

- Human activities
- Natural causes
- Don't know

3.What changes do you think is happening due to climate change

Sl.No	**Observation**	**Strongly agree**	**Agree**	**Neutral**	**disagree**	**Strongly disagree**
1.	Rising temperature					
2.	Draught					
3.	Flood					
4.	Sea level rising					
5.	Melting glaciers					

6.	Desertification					
7.	Heat strokes					
8.	Emerging new diseases					
9.	Reduction in food production					
10.	Increasing intensity and frequency of extreme weather events					

5. How much do you think that the following has contributed to global climate change?

Sl.No.	Observation	Very High	High	Not at all	Less	Very less
1	Deforestation					
2	Land use Land Cover changes					
3	Industrialisation					
4	Natural causes					
5	Fossil fuel emission					

6.Do you agree that Climate change poses human health risk?

Strongly agree

Agree

Neutral

Disagree

Strongly disagree

7.Which of the following health risk do you think can cause due to climate change? State your level of agreement.

Sl.No.	Observation	Strongly agree	Agree	Neutral	disagree	Strongly disagree
1	Infectious diseases					
2	Cancer					
3	Heat Stroke					
4	Breathing problems/respiratory diseases					
5	Sunburn					
6	Allergies					

8.According to you which of the following category is more prone to Climate change?

Sl.No	Observation	Very High	High	Not at all	Less	Very less
1	Urban dwellers					
2	People residing in rural areas					
3	People living in Coastal areas					
4	People in Forest Fringe areas					
5	Forest dwellers					

9. Have you heard of Urban Heat Island? Yes/No

10.'Temperature in urban centres is higher compared to rural areas' Do you agree with the statement.

Strongly agree

Agree

Neutral

Disagree

Strongly disagree

11.State your level of agreement on the following factors determining /maintain the phenomenon of 'Urban Heat Island'?

Sl.No.	Observation	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Emission of Fossil fuel					
2	Type of construction materials used					
3	Lack of greenery					
4	Form and layout of the city					
5	High population density					

12.In your opinion, which of the following interventions you think can reduce UH

Sl.No.	Observation	Strongly agree	Agree	Neutral	disagree	Strongly disagree
1	Urban parks					
2	Green buildings					
3	Green pavements					
4	Green roofs					

5	Reducing use of AC					
6	Efficient Public transportation system					

13. What measures would you prefer to take if you feel it is too hot? State your level of agreement

Sl.No.	Observation	Strongly agree	Agree	Neutral	disagree	Strongly disagree
1	Move to shade place					
2	Turn on AC					
3	Turn on Fan					
4	Drink Water					
5	Change clothing pattern					

14.Do you think that the temperature is rising over the past decade?

Yes/Neutral/NO

15.Who do you think should have the main responsibility for tackling climate change? State your level of agreement.

Sl.No.	Observation	Strongly agree	Agree	Neutral	disagree	Strongly disagree
1	International organizations (e.g., the UN)					
2	The national government					
3	Local government					
4	Business and industry					

5	Environmental organization					
6	Individuals					

3. Are you willing to do any of the following measures to tackle climate change?

Sl.No.	Observation	Definitely	Probably	Probably won’t	Definitely won’t
1	Planting trees				
2	Use of Public transportation				
3	Use of energy efficient gadgets				
4	Walk to work				
5	Cycle to work				
6	Switch off fans and lights not in use				

APPENDIX - II

THE MEASURED AIR TEMPERATURE AND RELATIVE HUMIDITY

Date	Dr Rajendraprasad public park			Collectoral park			SN park		
	Temperature (°C)		Relative Humidity (%)	Temperature (°C)		Relative Humidity (%)	Temperature (°C)		Relative Humidity (%)
	Dry bulb	Wet bulb		Dry bulb	Wet bulb		Dry bulb	Wet bulb	
20-02-2023	31	27	76	29	26	79	29.5	26	76
21-02-2023	30	26	73	31	26	67	31	26	67
22-02-2023	30	26	73	31	26	67	30	26	73
23-02-2023	31	26	67	31	25	61	31	24	56
24-02-2023	33	23	42	32	24	51	32	26	62
25-02-2023	33	27	63	33	25	52	34	26	53
26-02-2023	31	27	73	32	26	62	32	24	51
27-02-2023	30	28	86	31	27	73	32	24	51
28-02-2023	33	24	47	32	25	56	32	25	56
01-03-2023	33	24	47	33	24	47	31	24	56
02-03-2023	31	27	73	31	26	67	30	25	67
03-03-2023	32	24	51	30	27	79	32	25	56
04-03-2023	33	27	63	31	25	61	34	24	43
05-03-2023	31	23	50	31	26	67	32	25	56
06-03-2023	31	23	50	31	26	67	31	25	61
07-03-2023	30	26	73	32	24	51	33	23	42
08-03-2023	30	26	73	33	23	42	32	25	56
09-03-2023	31	26	67	31	25	61	30	25	67
10-03-2023	33	26	57	31	22	45	30	23	55
11-03-2023	30	23	55	32	23	46	31	23	50

12-03-2023	31	24	56	31	23	50	30	23	55
13-03-2023	32	25	56	33	23	42	31	23	50
14-03-2023	31	26	67	31	26	67	30	24	61
15-03-2023	32	26	62	32	25	56	31	26	67
16-03-2023	29	22	54	31	26	67	30	26	73
17-03-2023	30	21	44	30	23	55	31	26	67
18-03-2023	30	21	44	30	26	73	30	25	67
19-03-2023	31	24	56	30	24	61	30	25	67
20-03-2023	33	28	68	31	25	61	30	26	73
21-03-2023	33	27	63	30	25	67	30	24	61

	Urban_Sparse 1			**Urban_Sparse 2**			**Urban_Sparse 3**		
	Temperature (°C)		**Relative Humidity (%)**	**Temperature (°C)**		**Relative Humidity**	**Temperature (°C)**		**Relative Humidity (%)**
Date	**Dry bulb**	**Wet bulb**		**Dry bulb**	**Wet bulb**		**Dry bulb**	**Wet bulb**	
20-02-2023	33	27	63	33	27	63	31	26	67
21-02-2023	33	27	63	32.5	27	65	32	27	68
22-02-2023	33	27	63	33	27	63	33	28	68
23-02-2023	33	25	52	33	25	52	34	26	53
24-02-2023	35	24	40	35	24	40	34	27	58
25-02-2023	31	26	67	34	24	43	32	25	56
26-02-2023	32	26	62	33	25	52	34	26	53
27-02-2023	31	26	67	32	26	62	33	24	47
28-02-2023	34	25	48	34	25	48	34	26	53
01-03-2023	34	25	48	33	27	63	32	27	68

02-03-2023	33	27	63	32	26	62	33	25	52
03-03-2023	34	25	48	33	24	47	34	26	53
04-03-2023	31	26	67	33	25	52	34	26	53
05-03-2023	32	24	51	32	27	68	33	27	63
06-03-2023	32	25	56	34	27	58	33	26	57
07-03-2023	33	27	63	33	25	52	34	26	53
08-03-2023	34	27	58	34	24	43	33	26	57
09-03-2023	34	27	58	33	27	63	31	27	73
10-03-2023	32	28	74	33	24	47	34	25	48
11-03-2023	31	26	67	34	25	48	33	24	47
12-03-2023	33	26	57	33	27	63	33	24	47
13-03-2023	32	26	62	35	26	49	34	25	48
14-03-2023	33	27	63	33	27	63	33	25	52
15-03-2023	33	27	63	33	27	63	32	28	74
16-03-2023	30	24	61	32	27	68	31	27	73
17-03-2023	33	25	52	31	26	67	30	27	79
18-03-2023	31	26	67	32	26	62	31	26	67
19-03-2023	33	27	63	31	25	61	31	26	67
20-03-2023	34	27	58	30	26	73	31	27	73
21-03-2023	34	28	63	29	26	79	32	25	56

APPENDIX - III

OBSERVATIONS

Date	Time	Dr Rajendraprasad public park			
		Temperature (°C)			
		Dry bulb		wet bulb	
		Outside	Inside	Outside	Inside
20-02-2023	15:45:00	33	30.6	27	27
21-02-2023	15:55:00	33	30	27	26
22-02-2023	15:45:00	33	30	27	26
23-02-2023	15:45:00	33	31	25	26
24-02-2023	15:45:00	35	33	24	23
25-02-2023	15:45:00	31	33	26	27
26-02-2023	15:45:00	32	31	26	27
27-02-2023	15:45:00	31	30	26	28
28-02-2023	15:45:00	34	33	25	24
01-03-2023	15:40:00	34	33	25	24
02-03-2023	15:45:00	33	31	27	27
03-03-2023	15:50:00	34	32	25	24

04-03-2023	15:50:00	31	33	26	27
05-03-2023	15:50:00	32	31	24	23
06-03-2023	15:50:00	32	31	25	23
07-03-2023	15:50:00	33	30	27	26
08-03-2023	15:45:00	34	30	27	26
09-03-2023	15:45:00	34	31	27	26
10-03-2023	15:45:00	32	33	28	26
11-03-2023	15:45:00	31	30	26	23
12-03-2023	15:40:00	33	31	26	24
13-03-2023	15:50:00	32	32	26	25
14-03-2023	15:50:00	33	31	27	26
15-03-2023	15:45:00	33	32	27	26
16-03-2023	15:55:00	30	29	24	22
17-03-2023	15:45:00	33	30	25	21
18-03-2023	15:50:00	31	30	26	21
19-03-2023	15:50:00	33	31	27	24
20-03-2023	15:45:00	34	33	27	28
21-03-2023	15:45:00	34	33	28	27

	Collectoral park				
	Time	Temperature (°C)			
		Dry bulb		Wet bulb	
		Outside	Inside	Outside	Inside
20-02-2023	16:00:00	33	29	27	26
21-02-2023	16:03:00	32.5	31	27	26
22-02-2023	16:00:00	33	31	27	26
23-02-2023	16:00:00	33	31	25	25
24-02-2023	16:00:00	35	32	24	24
25-02-2023	16:00:00	34	33	24	25
26-02-2023	16:00:00	33	32	25	26
27-02-2023	16:00:00	32	31	26	27
28-02-2023	16:00:00	34	32	25	25
01-03-2023	15:55:00	33	33	27	24
02-03-2023	16:00:00	32	31	26	26
03-03-2023	16:05:00	33	30	24	27
04-03-2023	16:10:00	33	31	25	25
05-03-2023	16:05:00	32	31	27	26

06-03-2023	16:05:00	34	31	27	26
07-03-2023	16:05:00	33	32	25	24
08-03-2023	16:00:00	34	33	24	23
09-03-2023	16:00:00	33	31	27	25
10-03-2023	16:00:00	33	31	24	22
11-03-2023	16:00:00	34	32	25	23
12-03-2023	15:55:00	33	31	27	23
13-03-2023	16:05:00	35	33	26	23
14-03-2023	16:05:00	33	31	27	26
15-03-2023	16:00:00	33	32	27	25
16-03-2023	16:05:00	32	31	27	26
17-03-2023	16:00:00	31	30	26	23
18-03-2023	16:05:00	32	30	26	26
19-03-2023	16:03:00	31	30	25	24
20-03-2023	16:02:00	30	31	26	25
21-03-2023	16:00:00	29	30	26	25

	SN park				
	Time	Temperature (°C)			
		Dry bulb		Wet bulb	
		Outside	Inside	Outside	Inside
20-02-2023	16:10:00	31	29.5	26	26
21-02-2023	16:16:00	32	31	27	26
22-02-2023	16:05:00	33	30	28	26
23-02-2023	16:15:00	34	31	26	24
24-02-2023	16:15:00	34	32	27	26
25-02-2023	16:15:00	32	34	25	26
26-02-2023	16:15:00	34	32	26	24
27-02-2023	16:15:00	33	32	24	24
28-02-2023	16:15:00	34	32	26	25
01-03-2023	16:10:00	32	31	27	24
02-03-2023	16:15:00	33	30	25	25
03-03-2023	16:20:00	34	32	26	25
04-03-2023	16:20:00	34	34	26	24

05-03-2023	16:20:00	33	32	27	25
06-03-2023	16:20:00	33	31	26	25
07-03-2023	16:20:00	34	33	26	23
08-03-2023	16:15:00	33	32	26	25
09-03-2023	16:15:00	31	30	27	25
10-03-2023	16:15:00	34	30	25	23
11-03-2023	16:15:00	33	31	24	23
12-03-2023	16:10:00	33	30	24	23
13-03-2023	16:20:00	34	31	25	23
14-03-2023	16:20:00	33	30	25	24
15-03-2023	16:15:00	32	31	28	26
16-03-2023	16:17:00	31	30	27	26
17-03-2023	16:10:00	30	31	27	26
18-03-2023	16:15:00	31	30	26	25
19-03-2023	16:15:00	31	30	26	25
20-03-2023	16:17:00	31	30	27	26
21-03-2023	16:15:00	32	30	25	24