Evaluating Downtown Urban Heat Island Effect : The Case of Adama City, Ethiopia

Ayalnesh Shawul Tessema

A Thesis submitted to the Department of Architecture

School of Civil and Engineering and Architecture

Presented in partial fulfillment of the requirement for the Degree of
Masters of Science in Environmental Architecture

Office of Graduate Studies
Adama Science and Technology University

July, 2023

Adama, Ethiopia

Evaluating Downtown Urban Heat Island Effect: The Case of Adama City, Ethiopia

Ayalnesh Shawul Tesema.

Advisor; Sileshi Azagew (PhD)

A Thesis submitted to the Department of Architecture

School of Civil Engineering and Architecture

Presented in partial fulfillment of the requirement for the Degree of
Masters of Science in Environmental Architecture

Office of Graduate Studies
Adama Science and Technology University

July, 2023

ASTU, Adama, Ethiopia

DECLARATION

I hereby declare that this Master Thesis entitled **"Evaluating Downtown Urban Heat Island Effect: The Case of Adama City, Ethiopia"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Ayalnesh Shawul Tesema	______________________	_______________
Name of student	Signature	Date

RECOMMENDATION

I, the Advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled **"Evaluating Downtown Urban Heat Island Effect: The Case of Adama City, Ethiopia,"** prepared under my guidance by **Ayalnesh Shawul,** submitted in partial fulfillment of the requirements for the Degree of Master of Science in Environmental Architecture. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

Sileshi Azagew (PhD)	______________________	______________
Major Advisor/Supervisor	Signature	Date

APPROVAL SHEET

I, the advisor of the thesis entitled **"Evaluating Downtown Urban Heat Island Effect: The Case of Adama City, Ethiopia,"** developed by Ayalnesh Shawul Tesema, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Sileshi Azagew (PhD)	______________________	______________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by **Ayalnesh Shawul**, have Read and evaluated the thesis **"Evaluating Downtown Urban Heat Island Effect: The case of Adama City, Ethiopia"** and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the Degree of Master of Science in **Environmental Architecture.**

______________________	______________________	______________________
Chairperson	Signature	Date
______________________	______________________	______________________
Reviewer 1	Signature	Date
______________________	______________________	______________________
Reviewer 2	Signature	Date

Finally, approval and acceptance of the thesis are contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

______________________	______________________	______________________
Department Head	Signature	Date
______________________	______________________	______________________
School Dean	Signature	Date
______________________	______________________	______________________
Office of Postgraduate Studies,	Dean Signature	Date

ACKNOWLEDGMENT

First of all, I would like to start by thanking the Almighty GOD for all his support in my life. I wish Glory to my Lord Almighty for His care and smoothening challenges in doing all my steps from the Start to the end of this research. Next, I Would like to extend my special thanks to my advisor Dr. Sileshi Azagew (PhD), for his discussions, suggestion, contribution, guidance, and constructive comments during this research. I would also like to express my great appreciation to my staff members for all their suggestions and encouragement.

Deep appreciation and thanks go to the Ethiopian Metrological Agency of the Adama branch and Adama referral hospital for their assistance in providing necessary documents and sharing ideas for this research. Additionally, my special thank goes all 4 data collectors and 199 questionnaire survey respondents for their willingness to participate in this study.

Finally, I would also like to give special thanks to my family, who supported me during the whole period of my MSc study. Any time, they acknowledged my work and encouraged me to carry on. Without their encouragement and advice, I could not have achieved this success. Your prayer for me was what persisted me this far; thank you much. And thanks to all my friends, Ashenafi Mullu and Eyerusalem Shawul, for giving me their time and helping me during data collection.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

CAD	Computer-aided design
ENV_MET	Environmental Meso-scale Model.
ERDAS	Earth Resources Data Analysis System.
EPA	Environmental protection agency
E-W	East to west
GIS	Geographic information system
LULC	Land use land cover
LST	Land surface temprature
NDVI	Natural vegetation index difference
NMA	National Meteorological agency
NGO	Nongovernmental organization
NVC	Natural Ventilation of the City
OLI	Operational Land Imager
TIRS	Thermal Infrared Sensor
RH	Relative humidity
SPSS	Statistical Package for the Social Sciences
S-N	South to North
SVF	Sky view factor
UCL	Urban canopy layer
UHI	Urban heat island
UV	Ultraviolet

ABSTRACT

The urban heat island is the main problem of larger cities and metropolitan areas across the world. Now a day's, developing countries like Ethiopia are characterized by high urbanization. As one of the cities of Ethiopia, Adama is also a rapidly urbanizing city, which resulted in impervious surfaces that caused an increase in temperature, especially in the inner part of the town. Accordingly, in the downtown area of Adama city, the magnitude of the urban heat island is increasing compared to the nearest rural areas, which affects the well-being and comfort of the inhabitant mostly in the winter season. Thus, the study intends to assess the causes and effects of urban heat islands and provide measures to Mitigate the downtown urban heat island effect of Adama City by analyzing the land surface temperature and estimating the spatial-temporal changes within the years 2013 and 2023. The study is conducted based on both qualitative and quantitative approaches using different models and data, arch GIS, Satellite images, and survey methods. The Primary data was acquired by using questionnaires, interviewing, and photography to identify the factors and effects of urban heat islands in the city. Secondary data like satellite images were also used. GIS software was the main computer packages used to analyze spatial-tempo data. The results of this study indicate that the magnitude of the urban heat island in the downtown area of the City is 5^{o}c to 7.5^{o}c. The area of non-vegetated and non-reflective surfaces has 75% (high) LST than those vegetated surfaces, which is 25%. On the other hand, the result of LU/LC change indicates that in the period between 2013 and 2023, the built area showed incremental changes by +1597ha, while shrubs and bare land decreased by -194 and (-649) ha, respectively. This confirms that the maximum UHI occurs because of the increasing built-up area. In addition, increasing the usage of low albedo material for paving as well as for different construction of the structure in the city has a high contribution to the increment of UHI in the study area. The finding also indicates an increase in UHI affecting the well-being of urban dwellers by causing discomfort and affecting the health of the residents, especially in the winter season. Therefore, this study recommends greening roofs, planting Vegetation along the roadside and buildings, improving pavement materials, promoting cool roofs and high albedo building materials, etc., for mitigating UHI in downtown.

Keywords; *Albedo, land surface temperature, normalized difference, Spatial-temporal, Urban Heat Island,*

CHAPTER ONE

INTRODUCTION

The study aimed to assess the causes, consequences, and measures to mitigate the downtown urban heat island UHI) effect in Adama City. The problem of urban heat islands can lead to a wide range of negative effects, including increased energy consumption, air pollution, and public health problems. Understanding where the temperature in the urban areas is higher than in surrounding rural areas due to different factors is crucial for a comfortable life in the city. Therefore, to mitigate downtown UHI, such kind of studies are mandatory. The motivation of the present study is the consciousness of several environmental and Socioeconomic problems caused by the rapid spontaneous urban development process. This research briefly states the problems related to urban heat islands and illustrates the importance of using modified methods to better understand how to mitigate of UHI effect. The inner cities have experienced an increase in new building construction throughout the city. This has resulted in negative consequences, including increased infrastructure failure, decreased urban air quality, energy consumption, and even an increase in mortality rates and order, all of which adversely impact inner-city thermal comfort.

This research would ultimately look towards a solution that responds to the urban heat island of the downtown, seeking vegetation cover and cooling environmental strains, in a specific downtown, through sustainable intervention. And also, it is apparent that the benefits of mitigation of UHI are vast, and particularly for a downtown city like Adama, study in this field can bring about timely intervention in urban policies to result in energy savings and outdoor thermal comfort.

1.1 Background

Urbanization is the main anthropogenic process responsible for radical changes like the atmospheric and surface characteristics of the world. In most large cities, the temperature at the heart or the center of the city is noted to be higher than its surroundings or the suburban area. The phenomenon is known as Urban Heat Island Effect; in other words, cities demonstrate greater temperatures in their center than the outskirt areas, which is called the urban heat island effect (Yamamoto, 2005).

The growth of cities in African countries has accelerated during recent decades, leading to environmental problems of a different nature. Local climate also changes as the urban areas grow. The most well-known change is the onset of an urban heat island (UHI), a phenomenon studied in mid-latitude cities throughout the 20th century (Jáuregui & Luyando, 1999). The UHI generates different effects in tropical and temperate cities. The cost of an overheated tropical city can be evaluated in terms of decreased human comfort and increased costs of air conditioning and refrigeration (Republic, 1999).

Presently most tropical cities, the presence of heat islands throughout the year has been established. In addition, most of these cities exhibit a seasonal variation in the intensity of the UHI. Usually, the dry season is the period of maximum heat island intensity, both in the wet and dry tropics, the city of Addis Ababa, Ethiopia, whereas there is a 2.7°C UHI in the dry season (Kifle, 2003).

The urban heat island effect (UHI) is the warming of air due to the physical properties of urban. Land covers and the altered ventilation patterns due to building configurations. Urban areas Generally have warmer air temperatures relative to rural or suburban areas (Stewart, 2011).

There forms a temperature difference between the cities and the surrounding suburbs because of the effect (Yamamoto, 2005), which causes discomfort to the city dwellers. When a huge amount of natural land is replaced by an artificially built surface that absorbs incoming solar radiation or heat and re-radiates it at night, it develops (Oke, 1982).

As development continues in Ethiopian cities like Adama, natural habitats are being converted to non-vegetated covers. This would increase the warming of air due to the physical properties of urban land covers and the altered ventilation patterns due to building configurations.

1.2 Statement of the problem

In Adama, almost in all parts of the city, anyone can see that there is urban development and new building construction throughout the city. The effect of the city on outdoor temperatures may often warrant serious considerations. High environmental temperatures are harmful to health and comfort, and continued exposure can be instrumental to the incidence of stroke, heart disease, and respiratory disorders (Gartland, 2009).

The basic argument why this study is proposed and done in East Shewa Zone Adama city is that according to the data from the Ethiopian metrological agency, Adama city climate has variation in monthly temperature than previous years. For instance, the highest temperature recorded during the winter season in the year 2023 is from January to March, which ranges from 26^{o}c - 30^{o}c.

According to measured data from the field during sunny and clear sky days, the temperature variation of the inner city or downtown area of Adama extends from 5^{o}c to 7^{o}c when compared to the nearest rural and sub-urban areas (recorded data from the field by the researcher), As a result of the increased temperature of downtown, the well-being and comfort of dwellers were affected.

Therefore, it is important to investigate the causes of the increment in temperature in the inner/downtown part of the city. Furthermore, no research has been done in Adama on the cause and effect of urban heat islands on outdoor environmental temperature. Even though some studies were focused on UHI, they lacked detailed investigation into the cause and consequences of UHI in the city. For instance, Warkaye et al. (2018) identified that the UHI effect is mostly caused by heat stored through buildings, roads, and parking lots during the day. Moreover, to mitigate this problem, they are mainly focused on urban greenery (Warkaye et al., 2018), expanding green parking on the street (Malik, 2016), or mainly focusing on building materials (Zhong et al., 2021). However, this study aims to identify and evaluate the causes of UHI from different angles, like changing Albedo materials, and to come up with several mitigating techniques that make a comfortable outdoor thermal environment. Hence, this study is intended to fill these gaps and come up with a design solution that should be considered before urban development and new building construction throughout a city.

1.3 General Objectives

The general objective of this research is to assess the causes and effects of urban heat islands and provide measures to Mitigate the downtown urban heat islands effect in Adama City.

1.3.1 Specific Objectives

1) To analyze spatio-temporal land surface temperature change for the years 2013 and 2023 in Adama City.
2) To analyze factors for the increasing heat island problems in Adama city.
3) To investigate the effects of urban heat islands in Adama city.
4) To come up with design solutions to Mitigate Urban heat islands.

1.4 Research questions

1) What are the spatio-temporal land surface temperature changes in the years 2013 and 2023 in Adama City?
2) What are the factors for the increment of the downtown heat island in the City?
3) What are the effects of urban heat islands?
4) What are the design solutions for the urban heat island effect?

1.5 Significance of the Study

The outcome of this study would guide the planning and designing system, especially the new step the planning system has started to take in terms of local development planning and design.

The study is also expected to add some consideration to the status of the planning and designing. a system with an emphasis on the need for more design solutions and more efficient mechanisms That enables the planning and designing system to contribute towards ensuring the quality of living conditions for downtown area dwellers since the research focuses on mitigating downtown heat island.

It would be an important document, and it would use as a reference for considerable things during different development in the town for government officials, Non-Governmental Organizations (NGOs), the community, environmental advocates, etc. Furthermore, the output would be an important input for the academia to debate and propose a new and/or improved form of interventions in the inner city developments. Moreover, the findings of this study were an initial input for future research direction for interested groups in the area.

1.6 Scope of the Study

The study is conducted within the current boundary of Adama City lies in the geographical. location of 8°26 ′15″N to 8°37 ′00″N latitude and 39°12′15″E to 39°19′45″E longitude. The **spatial** scope of this research is limited to Adama city, focusing on the downtown area around the Posta area along the way to the Abro Godana area. The **thematic** scope of this research involves building form and orientation, street layout, material, and landscape used in the downtown area, and forwarding solutions and mitigation measures to create a safe, habitable, and comfortable downtown urban environment. cause.

1.7 Limitations of the Study.

The study has faced many problems. It was challenging to measure every environmental variable hourly and minutely during the measurement time. The political situation in Ethiopia was a big limitation to collecting detailed surveys and the occupant’s responses. Furthermore, throughout the data-gathering stage, certain informants' willingness was difficult.

The study focused on the spatial aspect, and the other aspect, like practical temperature measurement very difficult for the study. The effect of land cover assessment needs more time; this can be achieved as much as possible. Office bureaucracy was the other challenge of the project in accessing secondary data, especially obtaining the metrological data of the town.

1.8 Organization of the Report

The paper consists of five chapters. Each chapter systematically and effectively examines the content and data of the study accordingly. The fundamental chapters in the thesis are We further demonstrated this as follows.

Chapter One - Introduction to the study introduced the thesis by lighting the main topic of the study, research problems, objectives, questions, significance, scope, and research design in detail.

Chapter Two- deals with a literature review. This chapter describes the theoretical review starting from defining the key terminology to a general assessment of urban heat island, types, causing factors, and measure taken to prove the problem contextual of the global level practices and measures used to mitigate the effect of the urban heat island.

Chapter Three - is about methods and materials. It explains the methods used for the study and the process of data collection and analysis in detail.

Chapter Four- Result and Discussion. It also includes the results of processed satellite images, field data collection, land use, building material, and analysis of LST, LULC, and NDVI. It analyzes the data from results to determine the affected urban heat island and comparisons traverses of E-W and S-N directions.

Chapter Five- Conclusion and Recommendation. Based on the result and discussion study's recommendations and conclusions are presented in the last chapter. Finally, the Reference, UHI checklist, and different formats of questionnaires are given in Appendixes I to V.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Urban Heat Island (UHI)

An urban Heat Island is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. Temperature differences are usually greater at night than during the day and are most pronounced when the wind is light. UHI is most pronounced in summer and winter (Voogt & Oke, 2003).

The Urban Heat Island (UHI) is the warming of air due to the physical properties of urban land covers and the altered ventilation patterns due to building configurations. Urban areas generally have warmer air temperatures relative to rural or suburban areas (Stewart, 2011; al., Solecki et, 2005)

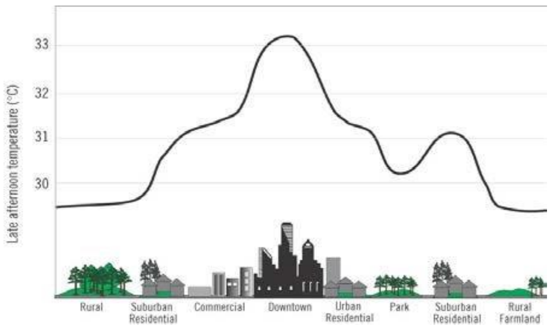


Figure 2:1 A typical UHI profile (Reproduced from EPA, 2009)

2.1.2 Urban Heat Island Types

2.1.2.1 Surface Urban Heat Islands

Surface UHI is also called remotely sensed UHI because it is usually observed using infrared. Data that allow retrieving land surface temperatures. Surface Urban Heat Islands are typical. Present at daytime and nighttime but tend to be stronger during the night (Dewan, 2021). On sunny and hot summer days. The sun can heat dry, exposed urban surfaces, such as sidewalks and roofs, to temperatures higher than the air temperature. The average difference in daytime surface temperatures between the urban and rural areas is 5 to 10°C, and the differences in nighttime surface temperatures are typically 10 to 15°C, considered higher than the daytime differences (de Almeida 2021). Surface UHI varies seasonally and is usually greater in the summertime due to changes in the incoming solar radiation and drier weather conditions associated with summer in most regions (Dewan 2021).

2.1.2.2 Urban heat islands in the Atmosphere

In urban areas, the warmer air compared to the cooler air in nearby rural areas defines the atmospheric urban heat islands. This heat island was divided into two different types:

Boundary layer Urban Heat Islands: This layer starts at the roof level and extends to the point where the cityscape no longer affects the atmosphere. This area typically does not extend more than (1.5 km) above the surface (Oke, 1995).

Canopy layer Urban Heat Islands: These exist in the layer of air where people live, usually extending from the ground to below the tops of vegetation and roofs.

2.1.3 Urban Heat Island Formation and Affecting Factors

The formation of UHI is determined by several factors, such as vegetative cover availability, land cover, properties of urban materials and geometry, as well as the geographical location of cities. Large water bodies or mountainous terrain located near the cities can influence the general wind patterns, which in turn could influence UHI formation (USA Environmental Protection Agency, 2008).

2.1.3.1 Urban Geometry

Urban geometry refers to the dimensions and spacing of buildings within the city. The influence of city geometry influences energy absorption, wind flow, and the surface's ability to emit long-wave radiation back to the sky. The effect of urban geometry is very obvious during the nighttime since, in most developed areas, structures and surfaces are obstructed by objects, such as neighboring buildings; as a result, these areas become large thermal masses that cannot release their heat readily during the night due to these obstructions (USA Environmental Protection Agency, 2008). Surface geometry obstructs the sky (due to buildings and related objects) from the urban surface; this effect has been called the sky view factor.

2.1.3.2 The physical properties of urban materials

Typical urban materials include concrete, asphalt, metals, glass, and other artificial materials. These urban materials change the reflectivity and energy balance of land covers in several. Important ways. Found that only 15 -20% of the incoming shortwave radiation was reflected by urban areas while the remaining 80-85% was absorbed and stored by Urban materials. A measure of a material's reflectivity is called its albedo. The albedo is the ratio of incoming short waves of solar radiation to the reflected outgoing radiation. Measured from 0 -1.0, materials close to 0.0 reflect almost none of the incoming solar radiation, absorbing close to 100% of the incoming energy. New asphalt may have albedo values of 0.05 (Akbari, 2012).

New asphalt may also absorb close to 95% of incoming radiation. Second, urban materials alter the energy balance of land covers. Emissivity is the measure of a material's ability to store and Emit heat energy. It is measured from 0 - 1.0, where materials that approach 1.0 are efficiently stored. The heat releases slowly into the atmosphere. Concrete, asphalt, and brick emissivity values are around 0.90 (Wang & Zhou, 2019).

Finally, the heat energy stored in urban materials is emitted in one of three forms: 1) sensible. Heat, 2) longwave radiation, or 3) latent heat. Both sensible heat and long-wave radiation contribute to higher air temperatures. Sensible heat energy raises air temperatures through the process of convection (Stone, 2012). The convection process accelerates with higher wind speeds, more air turbulence, and larger temperature differentials between urban materials and the UCL (Gartland., 2009). Long-wave radiation warms the air indirectly through the greenhouse effect (Stone, 2012). Latent heat does not contribute to warmer air temperatures.

2.1.3.3 Vegetation Cover / Land Cover

The first category of physical drivers that influence UHIs formation is the conversion of land. Cover from rural to urban covers. Specifically, UHI formation is influenced by the relative. The proportion of urban impervious surface to naturally vegetated land covers. As urban areas develop and density increases, impervious pavement and building surfaces replace permeable soils and vegetation. Theeuwes et al. (2012)Found that in dense neighborhoods, every 10% increase in the percentage of vegetation in highly impervious areas resulted in a decrease in air temperature by 0.8^{0}C. Impervious surfaces limit the presence of moisture, which plays a key role in moderating local air temperatures.

The green cover generally helps to lower the surface temperature by providing shade and Also helps to reduce air temperatures through evapotranspiration (USA Environmental Protection Agency, 2008). During evapotranspiration, vegetation releases water vapor into the surrounding air, which contributes to reducing the air temperature. Conversely, urban areas are characterized by being covered by impervious and dry surfaces, such as conventional roofs, roads, and sidewalks. As a result of city development, more vegetation is removed and replaced by more sealed surfaces (i.e., buildings and paving). Any replacement of vegetation with buildings leads to less moisture and high surface runoff.

2.1.4. Atmospheric Factors

When wind speeds increase, turbulent mixing exponentially reduces the differences in air temperature near the surface. Moreover, the atmospheric humidity might reduce the net potential radiative cooling of the surface. Therefore high atmospheric humidity is likely to increase the heat island intensity Zhang et al., (2022). Low humidity areas such as high elevation and desserts locations could generate large air temperature drops.

2.1.5 Strategies to Reduce Urban Heat Island

According to Voogt & Oke (1997), urban heat island mitigation occurs in two ways. On the one hand, it increases the urban surface albedo, and on the other hand, it increases evapotranspiration. However, the main strategies for mitigating UHI effects are outlined below.

Shade Trees: Shade trees have large canopies that can protect your home and pedestrians. Avoid direct sunlight and store in a relatively cool place. Shade trees also help reduce temperatures through the evapotranspiration process.

Green Vegetation: Increasing the amount of vegetation is one of the most effective mitigation strategies Influence of urban microclimate (Theeuwes et al., 2012).

High Albedo Roofing Materials: A dark roof absorbs the heat of the sun and keeps the house warm. In contrast, light-colored roofs with similar insulating properties do not heat up significantly due to the reflection of solar radiation (Akbari 2012).

High Albedo Pavements: Roads and highway pavements made of high albedo materials can reflect more solar radiation (Akbari, 2012). Therefore, the correct choice of road surface material also helps reduce the effects of UHI.

Green Roofs: Urban rooftops occupy about 21-26% of the urban area. Therefore, if the roof is greened with vegetation, it contributes significantly to mitigating the UHI effect. Green roofs absorb heat and filter the air to reduce temperatures.

Water Bodies: The view is that an increase in the volume of water masses can lower temperatures due to their evaporative effects and increased wind speed (Robitu, 2006)). Also, due to the high heat absorption capacity of water, it can reduce the temperature of cities.

Pervious Pavements: Impermeable pavements do not allow water intrusion, and in this case, the cooling effect due to evapotranspiration is not significant (Sailor, 2006). Replacing the impermeable cover with a permeable cover that allows water to penetrate would reduce the temperature to a suitable level. Infiltrated water helps keep the pavement cool and directly affects temperature.

Urban Planning: Proper urban planning also plays an important role in the mitigation of the UHI effects. Yamamoto (2005) Explains the approach of urban planning on the riverbank. The proposal is to construct the building in such a way as to create a winding road through which cool air from the river can flow into the city.

2.2 Contextual Review

2.2.1 Planning for Urban heat island mitigation.

Extreme heat is the leading weather-related cause of death in the U.S. (Grundstein & Dowd, 2011). This is particularly of concern in urban areas due to the Urban Heat Island effect. The city of Boston is home to nearly 646,000 residents in 23 neighborhoods (The City of Boston, 2014). Currently, heat-related mortality in Boston is approximately 2.9 per 100,000 residents and is expected to triple in the next thirty. In this case study, UHI green infrastructure mitigation strategies conducted a Geographic Information Systems (GIS) and developed Boston-specific mitigation recommendations.

2.2.2 Urban Heat Island & Green Infrastructure

The Trust for Public Land launched a pilot project in partnership with the City of Boston. Climate-Smart Cities is built around four goals (Plan, The Trust for Public Land, 2008).

Protect - Establish waterfront parks, wetlands, and other lush coastlines to protect low-lying cities from rising sea levels, coastal storm surges, and other flood hazards.

Absorb – Create "water-smart" parks and greenways that naturally manage stormwater to reduce flooding, save energy for water treatment, and replenish drinking water supplies.

Connect – Connect walking and cycling pathways at the city level, providing zero-carbon transportation for all residents.

Cool – Planting shade trees and creating new parks to lessen the urban "heat island effect" that drives increased summer energy use and worsens heat waves. This case study provides the context on the UHI effect, green infrastructure mitigation strategies, and community engagement in the city of Boston, and the Recommendations section provides.

2.2.3 Impacts of urban heat island effect

There are three major ways that the urban heat island effect and the warmer temperatures it brings impact cities: 1) human health and comfort, 2) increased energy consumption, and 3) impaired air and water quality (Suszanowicz, 2019) guidance on how to implement green infrastructure solutions in the Boston context.

2.2.4 Green Infrastructure as Mitigation Strategy

They focus on three strategies for reducing urban temperatures: vegetation, roofs, and pavement. This section provides definitions, benefits, and considerations for each approach.

Cooling Benefits

Shaded walls had peak surface temperatures 9-36°F cooler than unshaded walls In Sacramento. In the study, tree shade reduced the surface temperatures of walls and buildings by 20-45°F (Akbari 1997). Cooler surfaces are important because they transmit less heat is released to the surrounding air, reducing the heat island effect.

Economic Benefits

Trees provide numerous economic benefits. First, trees can decrease residential energy use and Cost. These benefits can be observed in the summer by decreasing air conditioning needs and in winter as the wind-shielding effects of trees can reduce the amount of heat lost through Windows, doors, and other joints. The economic benefits of vegetation are not limited to residential buildings and energy costs. Finally, municipalities can find cost savings in trees through reduced pavement maintenance and stormwater retention. While large trees may require additional cleanup and repairs to sidewalks, their shade can extend the life of street surfaces and postpone costs for re-paving; well-shaded asphalt pavements need to be resealed every 20-25 years, compared to every ten years for unshaded streets (Forest et al., 2006).

Health and Social Benefits

In addition to improving health by cooling and filtering the air, shade trees provide protection. From ultraviolet light. Everyday exposure to the sun’s rays can increase the risk of skin cancer; Thus, shading areas where children play can reduce exposure to these harmful rays by about half. (Grant et al., 2002). Properly designed plantings of dense vegetation (e.g., a row of shrubs along a road and a row of Trees behind it) can reduce noise by 3 to 5 decibels (Nowak, 2007). Finally, trees improve community comfort in winter months by reducing wind speeds, making public spaces more comfortable and buildings less susceptible to heat loss.

2.2.5 Strategies for Mitigating UHI through green infrastructure

2.2.5.1 Landscaping Buildings

Plant trees to the southwest of buildings for optimal shading in the summer months. Such Plantings will also reduce building heat loss through walls, roofs, and cracks around windows, Doors and joints in winter months by slowing wind speeds by 20-80 percent (Thani, 2012).

Landscaping Streets and Parking Lots

Gartland Fernández (2009) provides two specific recommendations:

1. Plant trees at regular intervals (20-40 feet, depending on tree size at maturity) along both sides of a street and along any medians to shade the street, sidewalk, and parked cars.
2. Implement ordinances requiring that trees must shade 50 percent of parking lots within 15 years of construction (e.g., Davis and Sacramento, CA, have such requirements). This requires planting .5 – 2 trees per thousand square feet of a parking lot, depending on the canopy of the species of tree chosen.

2.2.5.2 Roofs

Green infrastructure interventions on buildings are effective and long-term solutions for the UHI. Effect Commonly implemented strategies include installing green roofs (vegetated roofs), cool Roofs (which have high solar reflectivity), photovoltaic panels, green walls, ventilation systems, and operable windows.(Arabi et al., 2015)

Green Roofs

A residential roof or green roof is a vegetated rooftop consisting of the following materials: plants, a lightweight, engineered planting medium, a filtration layer, a root barrier, a waterproofing membrane, insulation, the roof structure, and the building. Green roofs improve building energy performance and also the environmental conditions of the surroundings. Through shading and evapotranspiration, they help to moderate air temperature, decrease electricity consumption, reduce air pollution by filtering dust from the air, reduce rainwater input into the sewage system, and mitigate the risk of flooding (Suszanowicz, 2019).

Cool Roofs

Cool roofs reflect more It is lightweight, and absorbs less heat than traditional roofs. They reduce surface and air temperatures by minimizing the impact of solar energy due to the properties of alternative materials and by using white or light colors. There are two different types of cool roofs: low-sloped and steep-sloped cool roofs. Low-sloped cool roofs have higher solar reflectance, achieved by covering the existing material with a light-colored coating or single-ply membrane. According to the EPA, cool roofing products are made of highly reflective and emissive materials that can remain approximately 50 to 60°F (28-33°C) cooler than traditional materials during peak summer weather. Suszanowicz (2019) Three main benefits of cool roofs are reduced energy use, reduced air pollution and greenhouse gas emissions, and improved human health and comfort.

2.2.5.3 Pavement

Paved surfaces often cover between 25-50%of land in urban areas. The use of reflective and transmissivity coatings can help reduce UHI effects while providing many benefits. These benefits include but are not limited to improved stormwater management, prolonged. life of pavement, improved night-time visibility and, decreased energy use for lighting, reduced Noise pollution and increased opportunities for creative urban design.

2.2.5.4 Community Engagement for UHI

In an August 2012 presentation, the EPA offered four solutions to reducing urban heat: trees and vegetation, green roofs, cool roofs, and cool pavements, together with examples of voluntary efforts throughout the country (e.g., Climate Showcase Communities in fifty pilot local governments and tribal governments).

2.2.6 Lesson learned

In Boston City, heat-related mortality is increased from time to time, recently, it has reached approximately 2.9% per 100,000 residents, and also UHI affects comfort, energy consumption as well as impaired air. To reduce this problem, they developed a green infrastructure mitigation strategy; this strategy is concerned with three main strategic points. These are vegetation, green, cool roofs, and as well as pavement-related strategies, and also those implemented strategies have benefits related to cooling, economic benefit, health, and social benefit. To meet their strategy, they engage the communities for better improvement.

2.3 Empirical Literature Review

Mitigation of and adaptation to UHI phenomena: The Padua case study, Italy

Speaking specifically of Italian cities, heat islands are not caused by the anthropogenic heat Produced by human activities, but rather by urban surfaces (buildings, roads, parking spaces) will be released during the day and gradually during the night.

This effect creates a heat island at night because the heat released does not cool the city as much as the rural environment outside it.

2.3.1 Analysis methods: traditional surveys and remote sensing

The first part of the project addressed the implementation of efficient methods for studying urban heat islands. Immediately, we focused on creating a community development manual that could be used by other local governments. Against this background, they tried to use simple but effective methods. An ideal analytical process requires air temperature measurements throughout the urban environment.

The resulting imagery showed significant differences in night-time temperatures between urban and suburban rural areas. The nocturnal heat island, which intensifies at dawn, is already a leading indicator of the cause of urban overheating, mainly due to its morphology and surface finish (de Almeida et al., 2021).

To ensure and maintain the high effectiveness of the proposed interventions and solutions, the various overheating causes and problems in each area should be carefully identified, and site-specific strategies developed.

2.3.2 Feasibility Study

After processing the data for the area within the study transept, it was necessary to understand what remedial and adaptation measures should be considered based on the morphological aspects of this particular neighborhood of the city of Padua: buildings, outdoor public areas, and private spaces.

Through this process, they initiated a concrete project for the pilot area by adapting it to specific corrective actions that, until then, were general suggestions for other areas. Preliminary tests of the project carried out in the pilot area resulted in four different project scenarios.

Green ground: Scenarios where the permeation surface area of the area increases (from 18% to 23% by turning the paved parking lot into the lawn and planting 10m in height Trees along the main roads of the area.

Cool pavements: Alternative to the conventional pavement (albedo 0.2) and concrete (0.4 albedo) is used for roads and sidewalks with cool high albedo (0.5) materials.

Cool roofs: Replacing traditional tiled or covered flat roofs with 'cool' materials (0.3 to 0.6 albedo);

Green ground + cool pavements: A scenario in which both remedies are applied simultaneously.

2.3.3 Possible Transformations of the pilot area

It should be noted that the proposed measures alone may be effective in mitigating the heat island effect. However, to make effective and cost-effective decisions, we need more detailed information about the areas in which they apply.

The greatest impact is achieved when all these interventions are combined with more important urban and/or socioeconomic concerns in specific regions and become part of an overall climate change adaptation strategy.

> Intervention 0 actual conditions + summary of intervention 0 actual conditions Outdoor public spaces

> Intervention 1 + Overview of Intervention 1, Change the albedo of the road and change the reflectance of the road surface.

The first intervention shows an increase in the reflectance of the road surface. This can be done with different types of materials. Next, he considers two technical options. If more direct, it can affect pavement coloring/pigmentation. The other involves a more structured approach to asphalt modification.

> Intervention 2 + summary of intervention 2. Modify the albedo of sidewalks and parking lots. Modify the albedo of streets.

A second intervention also concerns the reflectance of impermeable urban surfaces. Parking lots and curbside parking lots were also considered to apply this intervention within the pilot area. These are usually paved and should be treated with a different approach, such as more permeable materials to better absorb rainwater.

> Intervention 3 + Overview of Intervention 3, Add greenery to public space grounds in addition to public trees. Public green space: Create new traffic islands and plant new trees.

A third intervention focuses on increasing public green space. Again, we're not talking about a nice new park or a big green space. These are micro-interventions that can be implemented in cities with integrated infrastructure.

> Intervention 4 + Overview of Intervention 4. Albedo on private pavement area. Change private surface reflectivity.

Intervention 5 + Overview of Intervention 5. Create green spaces on private land. Add green space to private land.

This intervention represents a gradual change in the roof of a civilian building. Change the reflectivity of flat surfaces to transform them into green roofs. Real The introduction of green roofs can only be realized if the city understands and appreciates its value in terms of the services it can provide to the community. It allows for heat island mitigation, rainwater lamination, air quality improvement, and, last but not least, recreational use.

Intervention 6 + Summary of Intervention 6. Green roof: Additional Scenario Intervention.

2.3.4 Lesson learned

According to their investigation, the Padua city UHI effect is mostly caused by heat stored in the Urban. Surfaces (buildings, roads, parking lots) during the day and then released gradually at night. To mitigate this problem, they integrate neighborhood proposals with different mitigation interventions those are; modifying Change, the albedo of roads, changing the albedo of sidewalks and parking lots, add green space to the ground in public squares in addition to public trees.

2.4. Conceptual Framework

The wind speed in the canopy layer is seriously decreased compared to the undisturbed wind speed, and its direction may be altered.

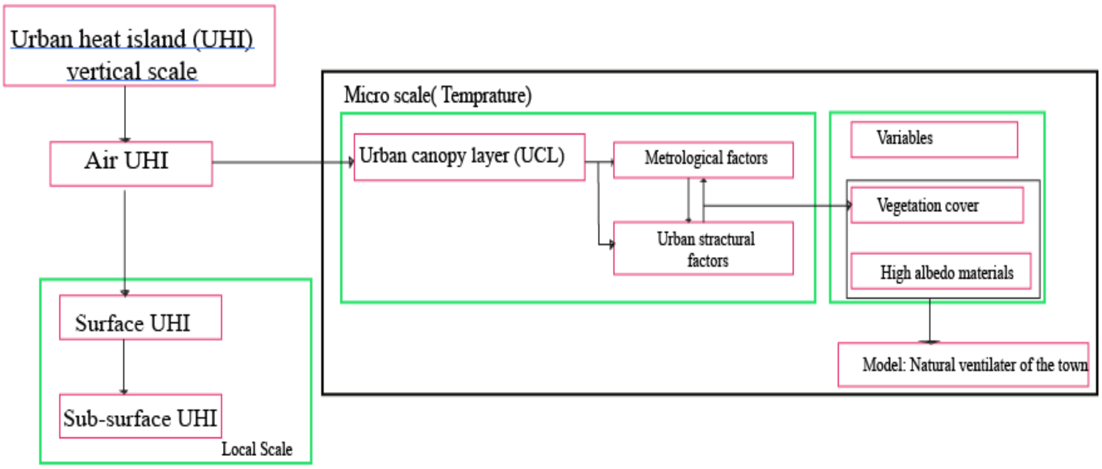


Figure 2.2. The conceptual framework of the study.

This is mainly due to the specific roughness of a city, to channeling effects through canyons, and also to UHI effects. In addition, higher temperatures increase the building density, photochemical pollutants, and the high humidity contributes to a hazy atmosphere.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Introduction

This chapter outlines the methods and materials which the researcher prepared to obtain and analyze data to assess the urban heat island conditions and map the Spatial-temporal pattern of urban physical characteristics of Adama using GIS. This chapter discusses and describes the methods that were used to obtain fairly accurate data. To collect data that will provide the necessary information for the objectives and research questions, the study adopted the qualitative research design as well as the mixed-method research approach. The research approach and design are discussed in-depth in this chapter. Therefore, this section gives a research approach and design and discusses the sampling technique and research instruments as well as data analysis tools.

3.2 Description of Study Area

Adama's downtown area is covered mostly by impervious surfaces, roads, buildings, and other structures, and the previous surface is inversely decreased radically from time to time and replaced by a jungle of concrete. This led to an increase in the downtown temperature. So to mitigate temperature increase, the downtown area is selected as a case study area.

3.2.1 Geographic Location

This research was conducted in Adama city, Ethiopia, which is located at 8°26 ′15″N to 8°37 ′00″N latitude and 39°12′15″E to 39°19′45″E longitude. It has an elevation that ranges from 1500 m to 1900 m above sea level. It is located in the East Shao zone of the Oromia regional state about 100 km southeast of Addis Ababa along the main road to Harar. Adama City was established in 1916 after the opening of the Addis Ababa-Djibouti railway line. The Great Rift Valley is to the east, and the foot of an escarpment is to the west of Adama city. Adama is a developing city in the region, with a city administration made up of 14 urban and four rural kebele.

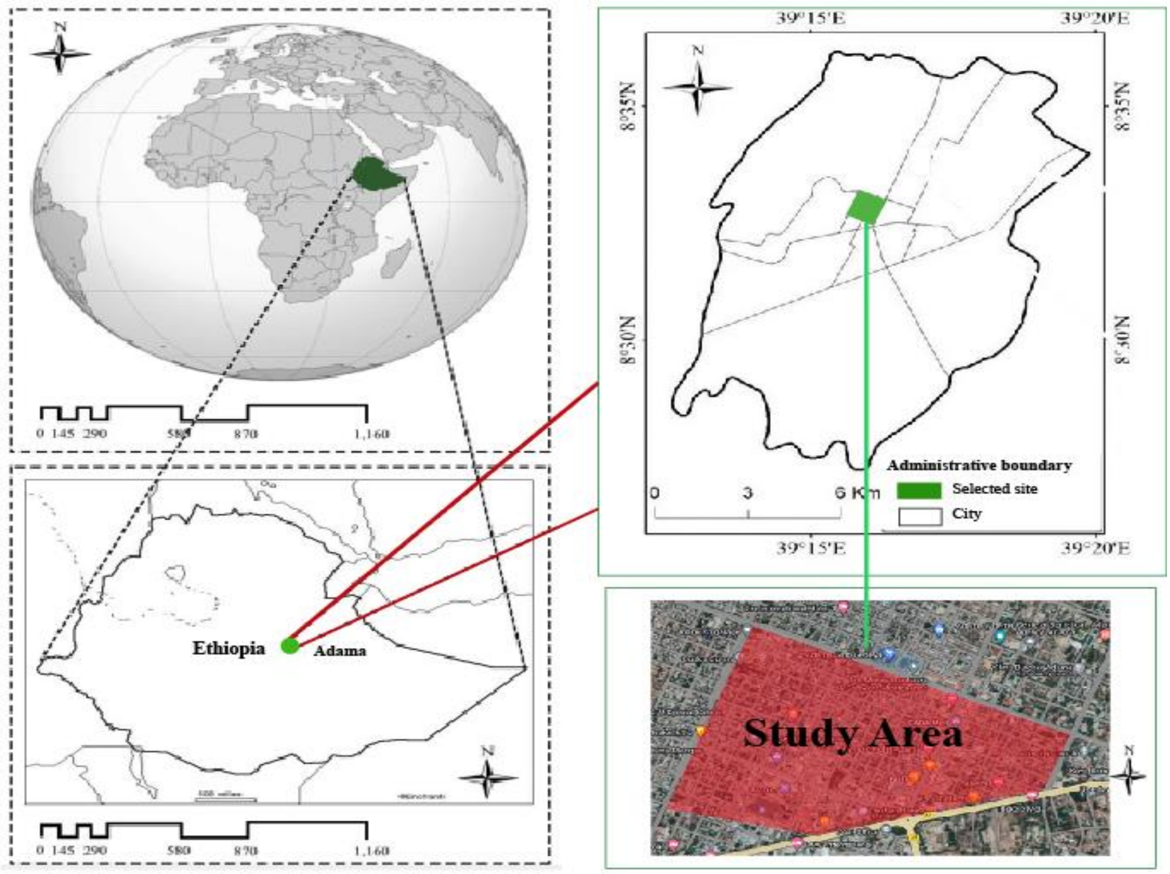


Figure 3.1: The Study Area

3.2.2. Climatic conditions of Adama

Monthly overheating

According to Figure 3.2, the climate consultant of time table plots January, February, and March, In the city of Adama but April and May are also the hot months.

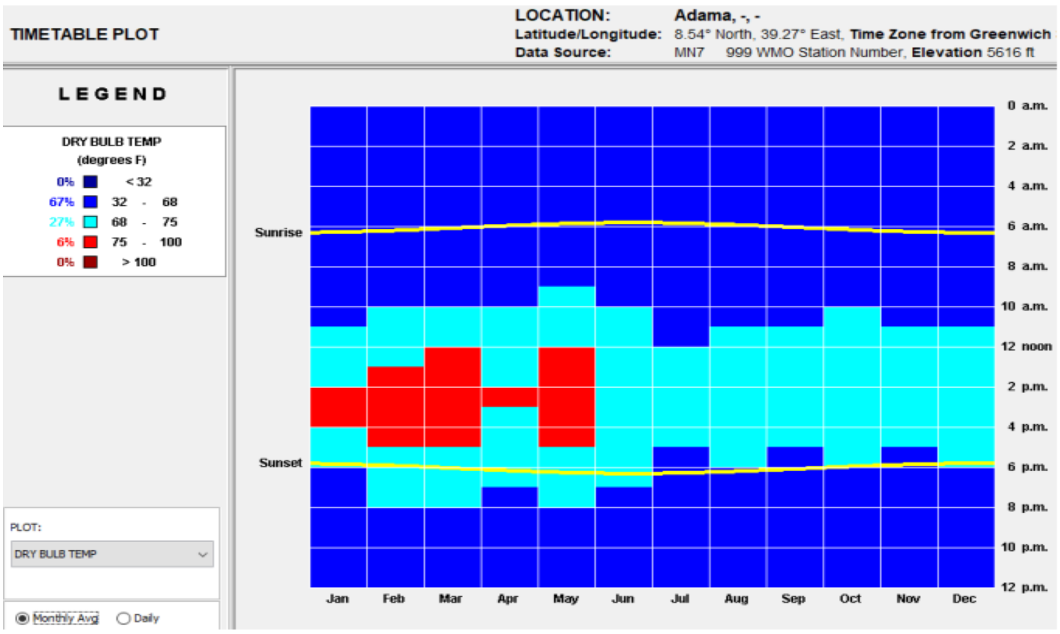


Figure 3.2 Overheating months of Adama

Average monthly day and night temperatures in Adama.

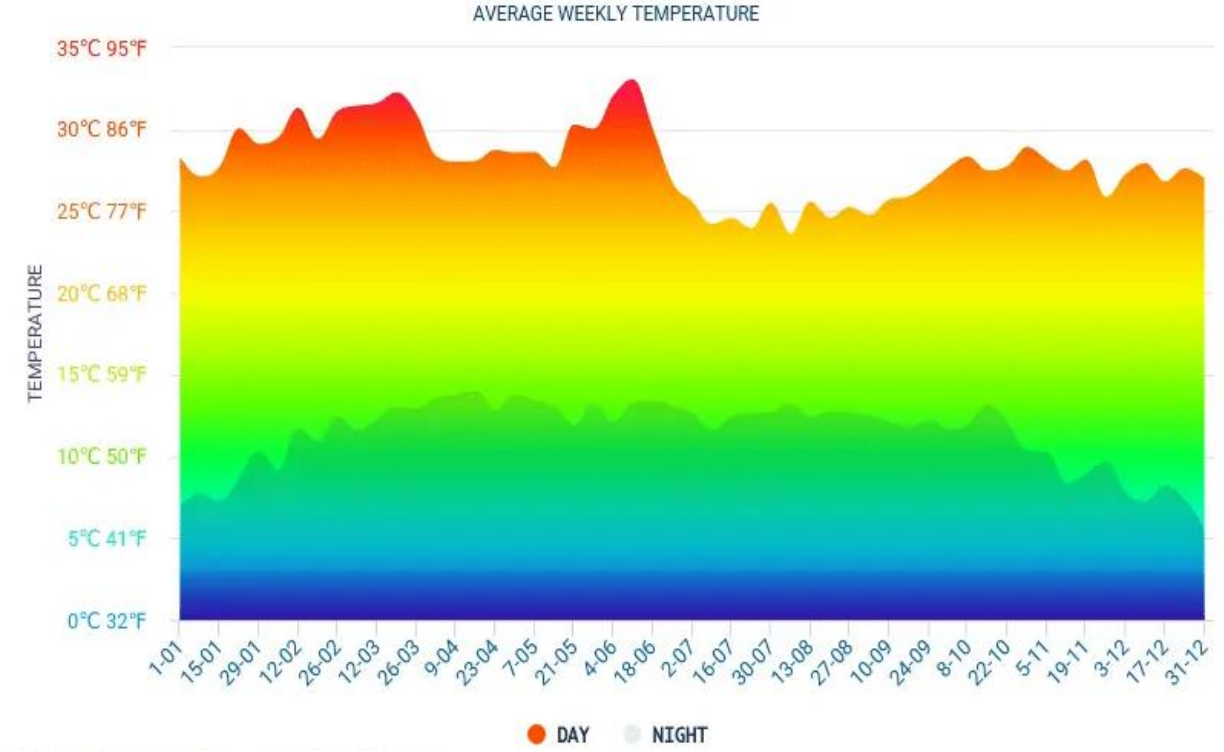


Figure 3.3 The day and night temperatures in Adama

Discomfort degree hours

Discomfort Degree Hours represent the total discomfort degree hours throughout the year Figure 3.4. Too cool represents in blue and reaches to maximum in July, and too hot represents in red and reaches to the maximum in March, April, and May.

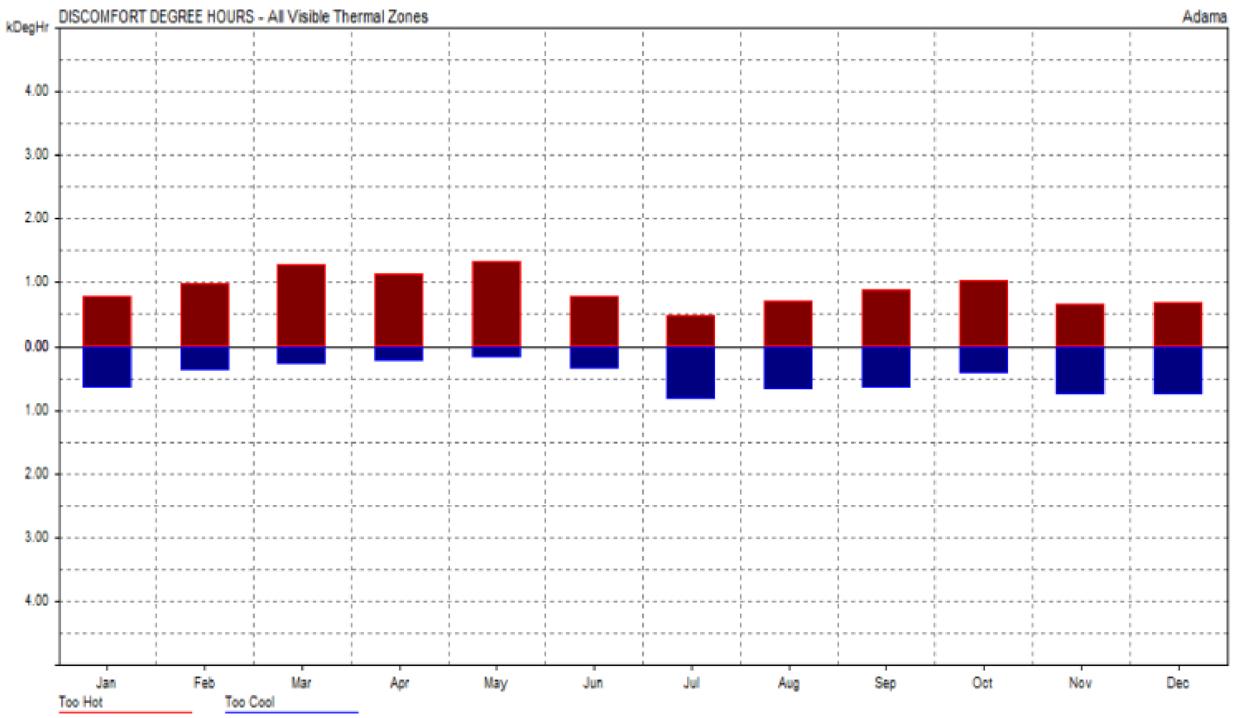


Figure 3.4: Discomfort degree hours of Adama

Daily Overheating:

When comparing the afternoon (12 pm-2 pm) and morning (8 am -10 am) temperatures, the morning temperature in Adama City is low Figure 3.5. According to Adama, the daily overheating temperature is higher in the midday (12 pm-2 pm) and declines in the late afternoon (4 pm-6 pm). As a result, the hourly overheating is at midday (12 pm-2 pm).

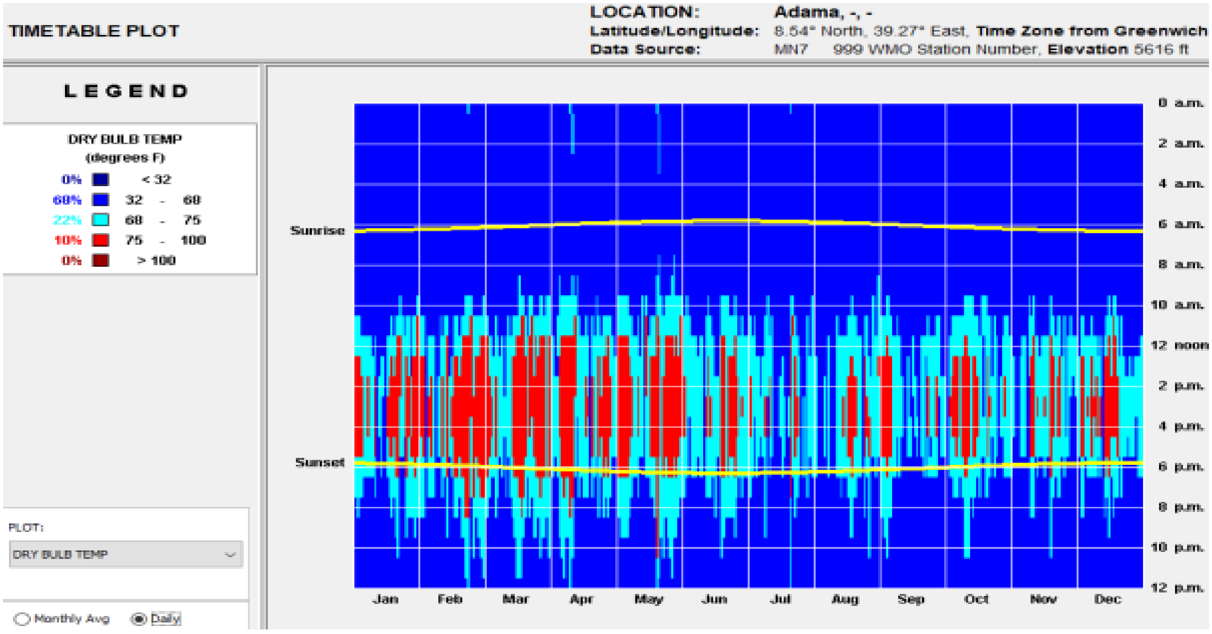


Figure 3.5 Daily overheating of Adama City

3.3 Research Design

Research design is a framework that guides researchers in how they receive and analyze information. It is helpful to have the most appropriate and viable way to test your hypothesis and answer your research questions. It puts researchers in an empirical world. In this study, the non-experimental design (survey) uses and adopts both quantitative and qualitative research methods were used (Figure 3.6).

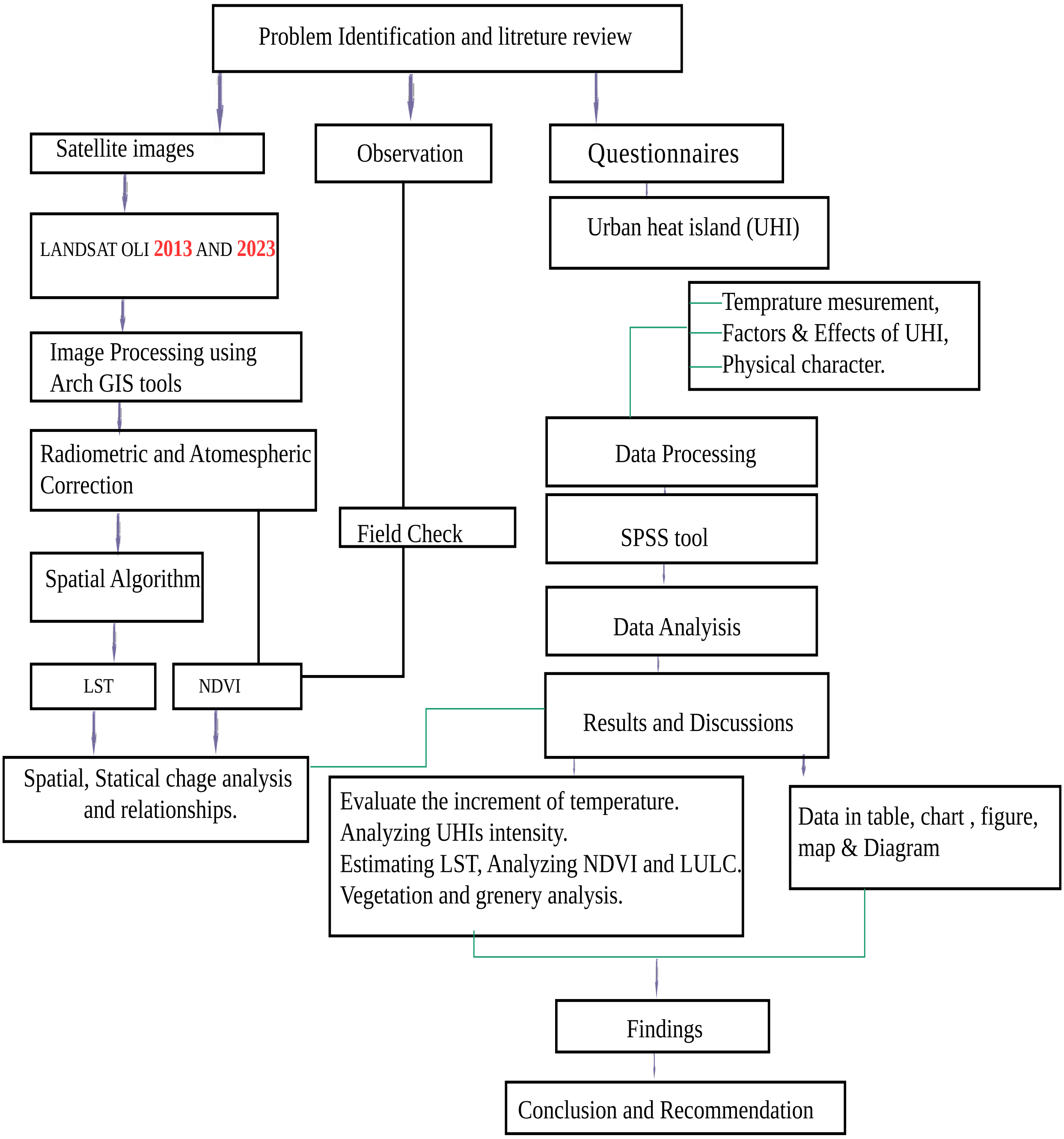


Figure 3.6 Research process diagram

3.4. Research Approach

The study applies a general deductive approach to the study. In this approach, researchers generate general information on specific information that allows them to collect both qualitative and quantitative data. A qualitative approach is important for gathering respondents' attitudes and experiences regarding outside worker comfortability and related issues. Quantitative approaches, on the other hand, are important for obtaining numerical data through questionnaires so that researchers can collect statistics in large-scale surveys.

3.5 Source of Data and Collection Techniques

Both primary and secondary data will be used to generate adequate information for this research. The primary data would be collected by interviewing the community (residents), related experts, and professionals and as well as through preparing a questionnaire for the local community and through observation of the site/ study area at different times of the day.

The secondary data would collect from the review of relevant information like published books, journals, and reports, and also the research relied on the data collected from related literature reviews, site visits, observations, and sample surveys.

3.5.1 Qualitative data collection techniques

The data that relate to concepts, opinions, and values, filed notes from observation of certain activities, and video recordings were collected qualitatively.

Observation method: To achieve the study's second objective, a questionnaire survey and an interview were used. One hundred ninety-nine questionnaires were printed and deployed by using 4 data collectors for 199 questionnaire respondents. Visits and observations made clearer the condition of the action area. Which focuses on the effect of UHI, is one sort of standardized questionnaire in the literature. The checklist would be used as the tool to aid in the observation, which would complement the other aspects by facilitating the observation of key aspects, which include the social structure, physical structure, land, and institutional structure of Adama city for later analysis.

In-depth interview: This involves asking, listening to, and recording answers from an individual or category in a structured, semi-structured, or unstructured format in an in-depth manner. Dweller's interview surveys the town community and their opinions on the site of dwellers.

3.5.2 Quantitative data collection techniques

Questionnaire: in the questionnaire, the main thing that helps to understand and estimate the level of thermal sensation and satisfaction scale is asking the questionnaire respondent, at a specific data collection time, what they perceive about the thermal environment at that specific time. The research would be based on quantitative data that would gather by preparing questionnaires (both closed and open questions) and interviews (group interview and individual) from the study area, the local community as well as the government office. Random sampling would be used to select the local community for interviewing and a questionnaire. The reson that a number of amount selected those are a number of manager working in that office is at two in number in their office.

Table 3.1 Summary of interview bodies and related experts.

No	Selected Sector for interview	The amount by no.	Selected body for interview
1	Oromia urban planning institute of East Shoa branch	2	Manager of the office and/ or urban planner
2	Adama city municipality office and Adama General Hospital	2	One Urban planner and one architecture
4	Ethiopian Metrological Office Adama branch	1	Office Manager

Field Survey method: This approach was used to examine the present state of the selected site under consideration by visiting the chosen field and independently assessing the current state of the urban heat island effect in Adama City by using different instruments (Table 3.2).

Table 3.2 Instruments used to measure Environmental variables in the field

Environmental indicator	Software/Test instrument	Specific objective	Analysis/material used
The clear comparative observation of the surface temperature of Adama in Landsat 7, 2013, and Landsat 8 images OLI 2023.	Arch GIS software. Illustrators for LULC.	To analyze the land surface temperature and land use and land cover temporal in the years 2013 and 2023 changes in Adama city.	To create shape files, then analyze LST, NDVI, LULC Spatial, statistical change analysis, and relationships and create mitigating solutions through envi-met simulations

The Physical characteristics of the site.	Field survey, Observation, Questioners and Interview	To Analyze the factors for the increasing urban heat island in the city	Building materials & their characteristics, Land use of the area, the morphology of the area, and Vegetation and Greenery Analysis
Outdoor Temperature and Relative humidity	**Thermometer And GPS**	To investigate the effect of Urban heat islands by measuring air temperature outdoors.	
A software tool that simulates the microclimate of urban environments	**ENVI_met 5.5**	To come up with constructive recommendations and solutions to measures to Mitigate Urban heat islands.	To analyze the effect of urban design on outdoor thermal comfort

<u>The material used to achieve the second objective for the study area</u>

To assess UHIs in Adama, mobile surveys were conducted during the winter season of calm, sunny, and clear sky days in the early afternoon to gather temperatures from different traverse routes. The measurements were performed using an infrared thermometer fixed on a 1.5-meter-long wooden rod attached to the side of the vehicle, and hand GPS was used to record the points where the data was recorded.

Data gathering involves traversing routes. Those east to west traverse and south to north traverse were selected. To cover the routes, approximately 1:30 was needed for each traverse. The route was 4 km long from east to west and 6 km long from north to south.

Field measurements are used for measuring the air temperature of the current situation of the Area. In this way, 20 points were selected in part of the district. Since only 2 hours were available to take measurements at sites of high radiation intensity, three consecutive days were chosen for this study to accurately measure these 2 hours. It investigated the relationship between temperature and different land uses in the current condition of Adama City.

Measuring UHIs in Adama City

Heat islands are defined by easily measurable parameters; typically, Satellite images to broad and visible instantaneous observed, and Air temperature is measured via thermometers via mobile measurements or fixed sensor networks. However, because of the financial difficulties of using fixed-point stations for short periods, mobile measurements across a town are efficient for assessing urban heat islands in Adama.

Mobile surveys have been extensively used in detecting UHIs in urban (Adama) and rural areas. (kebeles). The routes were a relatively linear and dense sample of temperatures in a relatively short period.

3.6 Methods of data analysis and Software

For this study, weather data from Adama City has been collected, and the research was carried out. All necessary information regarding dry bulb temperature, rainfall, and overheating seasons with their maximum, minimum, and average for all months of the year was imported from weather data and the NMA of Adama. This can also be observed in the interpreted data of the weather file by Adama metrological data and Climate Consultant.
Landsat 7 ETM+ (2013) and Landsat 8 OLI/TIRS (2023) were used to examine land surface temperature (LST) following Stemn (2020). All images were taken in the dry season with low cloud cover (<10%). Thermal bands in bands 6 and 10 of Landsat 7 and 8 images were used for LST analysis.

ArcGIS 10.3 software was used for LST, UHI, normalized differential vegetation index (NDVI), and normalized differential composition index estimation, and ERDAS Imagine 2015 was used for satellite imagery preprocessing and LULC classification. Google Earth was used to validate the LULC classes of 2013 and 2023. All datasets used for this analysis are shown in (Table 3.3). In addition to Landsat datasets, this study examined the role of topography in determining UHI.

Table 3.3 Datasets and Source

Satellite	**Sensor**	**Acquisition and year**	**Sources**	**Path/row**	**Resolution**
Landsat 7	ETM+	January 01, 2013	USGS	169/55	30 m
Landsat 8	OLI/TIRS	January 01, 2023		169/55	30 m
DEM	STRM				30m

3.6.1. Land use Land cover (LU/LC) Estimation

Land use and land cover classification are done using Landsat 7 ETM+ and Landsat 8 OLI/TIRS. A supervised classification method with a maximum likelihood algorithm was used to classify LULC into five classes. Already Rousta et al. (2018) classified LULC into four categories. (1) agricultural land, (2) vegetation, (3) built-up land, and (4) bare land.

3.6.2. LST transformation to UHI

To compare the variation of UHI from different dates, LST normalization methods were performed following Abutaleb et al.

Where:

$$\mathbf{UHI = \frac{Ts - Tm}{SD}}$$

TS=LST

Tm = Mean of the land surface temperature

SD = Standard deviation

3.6.3. Land Surface Temperature (LST)

Land surface temperature (LST) changes have been studied using different parameters and data sets to assess the heat effects in urban areas. Depending on landsat data, single window algorithm and split window algorithm are applied to generate LST output to assess the influence of urban green areas. During the present study, both these methods were used to retrieve LST from landsat TM, ETM+ and landsat 8 images. Correlation between LST and NDVI revealed that the latter is a good indicator of the former and that over 70% LST variability is due to randomly scattered distribution of the vegetation.

The process of obtaining LST values occurs after converting the thermal infrared digital numbers (bands 10 and 11) to upper atmospheric irradiance and satellite brightness temperature. The spectral radiance of the upper atmosphere was calculated using the following formula (Rajeshwari A, 2014).

Steps to calculate LST

The first step is to download a Landsat 8 image from a particular location, unzip it, and check certain information needed (within the metadata) to execute this procedure.

1. Calculation of TOA (Top of Atmospheric) spectral radiance.

$$\text{TOA (L)} = \text{ML} * \text{Qcal} + \text{AL}$$

where:

ML = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number). Qcal = corresponds to band 10.

AL = Band-specific additive rescaling factors from metadata (RADIANCE_ADD_BAND_x, where x is the band number).

$$\text{TOA} = 0.0003342 * \text{"Band 10"} + 0.1$$

Therefore, the equation must be solved using ArcMap's raster calculator tools.

2. Conversion from TOA to brightness temperature

$$BT = (K2 / (\ln (K1 / L) + 1)) - 273.15$$

where:

- K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number).
- K2 = Band-specific thermal conversion constant from the metadata
- (K2_CONSTANT_BAND_x, where x is the thermal band number).
- L = TOA

Therefore, to get results in degrees Celsius, adjust the radiant temperature by adding an absolute zero point (approximately -273.15 °C).

- BT = (1321.0789 / Ln ((774.8853 / "%TOA%") + 1)) - 273.15.

3. Calculate the NDVI

$$NDVI = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4)$$

Note that the calculation of NDVI is important because it needs to calculate the vegetation rate (Pv), which is strongly related to NDVI, and the emissivity (ε), which is related to Pv.

- NDVI = Float(Band 5 – Band 4) / Float(Band 5 + Band 4)

4. Calculate the proportion of vegetation P_v

- $P_v = Square ((NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min}))$

Usually, Min and max values of NDVI imagery can be displayed directly in the image (both ArcGIS, QGIS, ENVI, and Erdas Imagine). Otherwise, you will need to open the raster's properties to get these values.

- Pv = Square((“NDVI” +0.23958) / (0.659559 + 0.23958))

5. Calculate the emissivity ε

- ε = 0.004 * Pv + 0.986

Just apply the formula in the grid calculator. The value 0.986 corresponds to the correction value in the formula.

6. Calculate the Land Surface Temperature

$$LST = (BT / (1 + (\lambda * BT / c2) * Ln(\varepsilon)))$$

Generally, apply the LST equation to obtain the surface temperature map. The Value of λ for Landsat 8: for band 10 is 10.8. As a result of the process developed, there is a map of the Land Surface Temperature.

Flow chart of LST for 2013 and 2023 GC

The following is the most important critical step for computing LST.

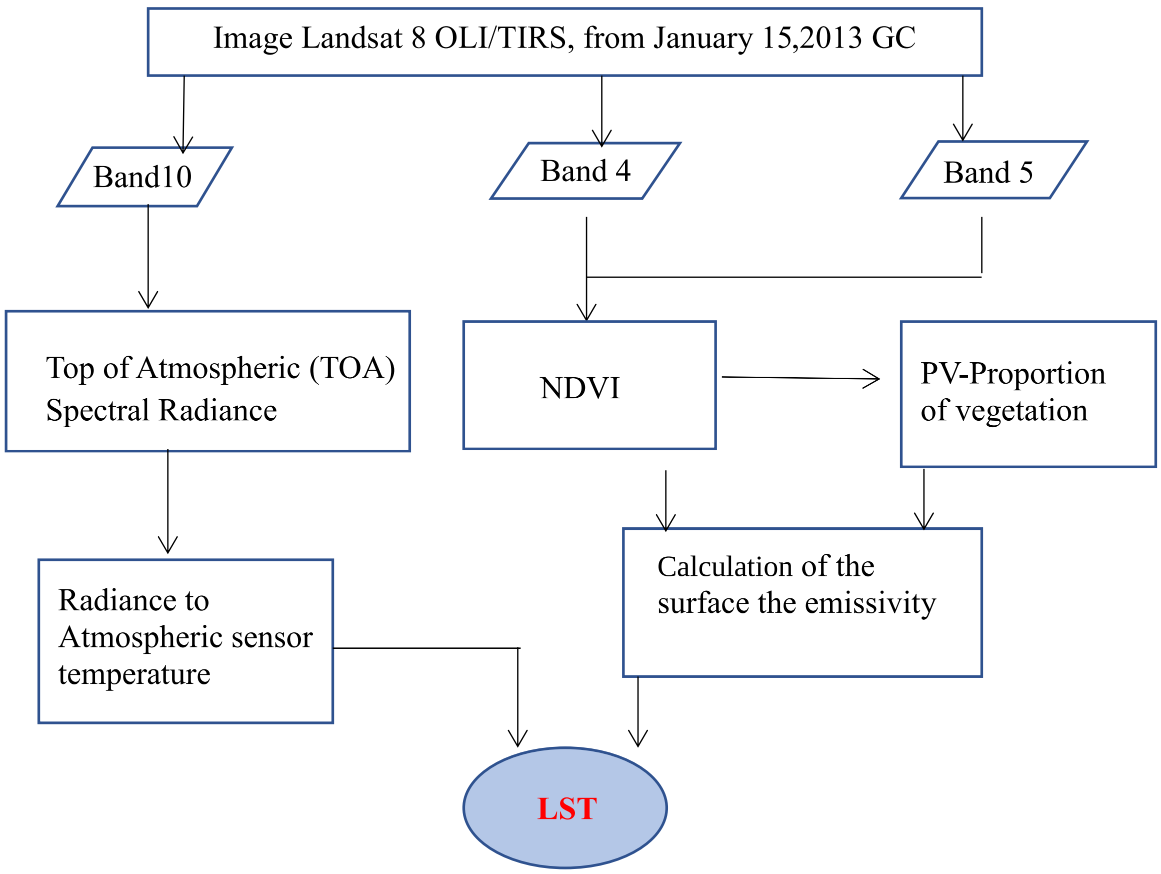


Figure 3.7 Low chart of LST for 2013 and 2023 GC

Flow chart of Correlating NDVI and LST

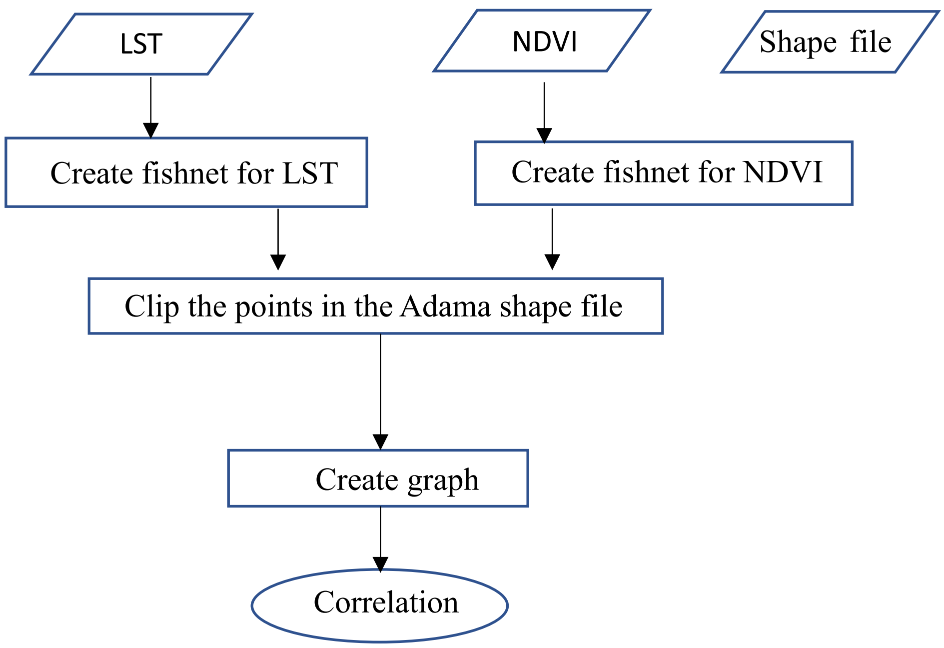


Figure 3.8 Flow chart of Correlating NDVI and LST

3.7 The Method Used for Simulation of Mitigation UHI

This ENVI-met is used to achieve to study the fourth objective for simulating the natural ventilator of the city model with three different scenarios. The Following charts show the process of simulations with ENVI-met.

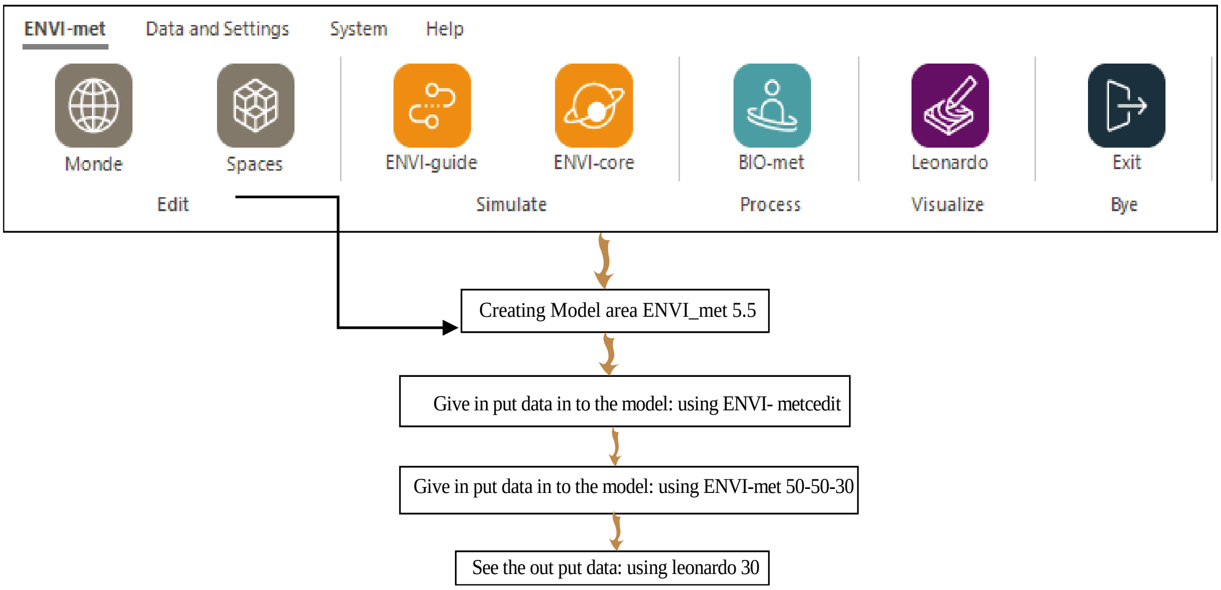


Figure: 3.9 Envi-met simulation process flow chart

3.8. Sampling technique

The study would be conducting an on-site pedestrian interview survey even though the total. The population is infinite. Since different stakeholders participate in the assessment of pedestrian Walkways, a random sampling technique would be used. The random sampling technique would be conducted by dividing the stakeholders into various classes/strata based on the purpose of their roles.

According to the unpublished document obtained from the Adama district administration. The total number of the most affected areas downtown households is 397. The statistical formula developed by Yemane (1967) was used to determine the sample size as follows:

$$\mathbf{n=\frac{N}{1+N(e)^2}}$$

Where:

n = sample size random surveys

N= Number of households (397)

Z = confidence level at 95% (standard value is 1.96)

Hence, using equation (1), the sample size was determined as follows: d = Desired precision (for example, 0.05 for ± 5%). e = designed level of precision with

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1+N(e)^2}} \quad \Big| \quad n = \frac{397}{1+397(0.05)^2} = \mathbf{199} \text{ no of participants}$$

Thus, the study would be conducted with a 199 Sample population size randomly for those who are convenient and willing for the interview.

3.8.1 Research population

The target groups of the survey are pedestrians, street vendors, and dwellers. Populations are selected by researchers based on their interest in pedestrians, the most affected group in the Area. In addition, government officials and street vendors are interviewed as key informants. By using judgment sampling techniques for the experts, It could be conducted in a cluster. Sampling method for street vendors.

3.8.2 Sampling Design and Techniques

Since different stakeholders participated, the assessment of the downtown urban heat island of Adama City stratified random sampling technique was used. The stratified random sampling technique is conducted by dividing the stakeholders into various statuses to identify the effect of the urban heat island on the residents of different living standards. The research population consisted of the dwellers in the city of Adama, especially downtown. The downtown dwellers were chosen because they are mostly affected by the effect. After all, the inner part of the town is characterized by a highly developed area and mostly covered by a jungle of concrete or pervious surfaces than the outskirt of the town. Accordingly, 199 people were selected based on the above-listed criteria from people who work in the buildings and jewelers.

3.9 Presentation and Interpretation

The Quantitative and qualitative data were analyzed and interpreted through descriptive, explanatory techniques and displayed using maps and graphics. And data interpret in an organized manner by using presentation techniques like Tables, charts, maps, and figures.

3.10 Ethical Considerations

Before beginning data collection, different participants were provided a consent letter to conduct the research. The study was extremely sensitive to the emotions, opinions, and dignity of the participants. The study purpose was thoroughly stated to the participants, together with how the data obtained from them was employed in this study. The knowledge gathered from the participants was only used for this specific research, and therefore the study kept the confidentiality of all individuals who participated in the study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Overview of Climatic Condition of Adama City

The climatic condition of Adama City has been described as a hot zone with a warm, dry season and a pleasant rainy season, according to the National Meteorological Agency (Table 4.1). Adama is located in the Great Rift Valley of East Africa. The summer season lasts from December to June, whereas winter lasts from June to September. Summer is hot and humid, with plenty of sunshine. The temperature is consistently high (average, lowest 27^{o}C, and maximum 33^{O}C) during this season, with less diurnal amplitude.

The humidity level is really low (average about 22 percent). The winter is hot and humid. The temperature is somewhat low (lowest 19^{o}C, and maximum 27^{o}C), and the humidity is considerable throughout this season (average about 40 percent). Throughout the year, the wind is mostly from the north and south. The mean monthly wind speed is from 1m/s to 5m/s in the winter and 0.5m/s to 4m/s in the summer.

Adama climate is characterized as a hot environment with severe heat during the day and A sharp decrease in temperature at night. The building business utilizes the most energy of all other industries due to the intense heat. The climate data of Adama during the study time showed the prominent wind direction was east-west. Location: Adama, Latitude: 8.54^{o} North, Longitude:39.27^{o} East, Elevation: 5616 ft. The time zone from Greenwich 3, Dara source: MN7 999 WMO Station number.

Table 4.1 The climate condition of Adama

Environmental indicators		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temperature (0C)	Max	28	30	33	35	34	31	25	25	26	29	28	27
	Min.	21	22	24	25	24	22	15	16	19	23	22	20
	Ann.	24	26	28	29	29	27	20	21	23	26	25	24
Humidity(%)	Average	50	48	37	24	25	56	62	60	44	39	36	45
Wind Speed (m/s)	Max	3	3	2	4	4	5	4	2	4	4	3	2
daylight (mph)	Average	11	11	12	12	12	12	12	12	12	11	11	11

Temperature

According to the records of meteorological information of Adama city, the maximum mean and minimum mean temperature of the town varies, are shown in Figure 4.1. In the winter season (March, April, and May), the highest recorded temperature ranges between 32ºc to 35ºc, which is the hottest season in the year

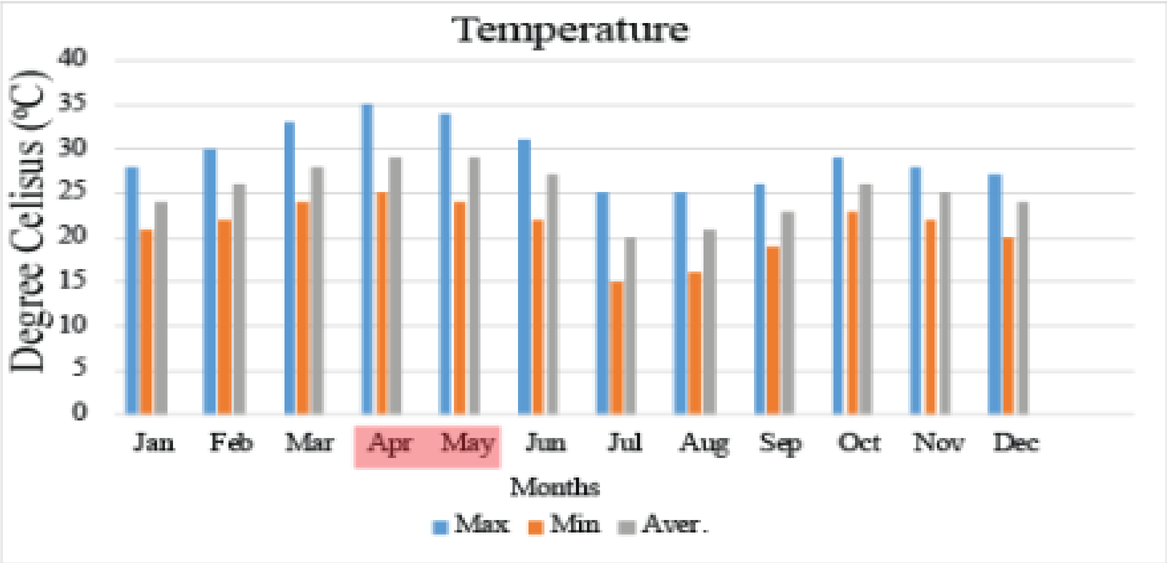


Figure 4.1 Maximum and minimum temperature of Adama.

Rainfall

According to Ethiopian metrological data, Adama City receives rainfall in June, July, August, and September, which are the rainy season of the city. According to the records of the city during the last five years (2017-2022), the mean monthly rainfall of Adama ranges from 175.8 mm – 207.2 mm.

Humidity

Relative humidity (RH) refers to the water content in the air compared to what the air can hold at that temperature. On average, Adama had 86.9%, 38.2%, and 62.6% maximum, minimum, and mean annual RH, respectively, during the years from 2017-2022.

Seasonal Overheating:

In Ethiopia, June, July, and August months are the summer seasons. February, March, April, and May months are the winter seasons, with frost in the morning, especially in January. Belg (Autumn) season includes the months of September, October, and November and is sometimes known as the harvest season. December and January are the spring months. April and May is the hottest month in Adama. Overheating months were March, April, and May. As a result, Winter is the overheating season.

4.2 Analayzing UHIs in Adama City

4.2.1 Urban Heat Island Measurement by using satellite image

The clear comparative observation of the surface temperature of Adama in Landsat 7, 2013, and Landsat image 8 images OLI 2023. The warm region, which is represented by a red and yellow color, is mostly located in the central, as was observed from the processed thermal images. The eastern, northeastern, and southeastern regions of the study area exhibited relatively high temperatures because it has barren and bare land covers that emitted more heat. The contrast between urban and rural areas hints at the prevalence of the UHI effect in Adama, although the satellite image only provides instantaneous observation during the daytime.

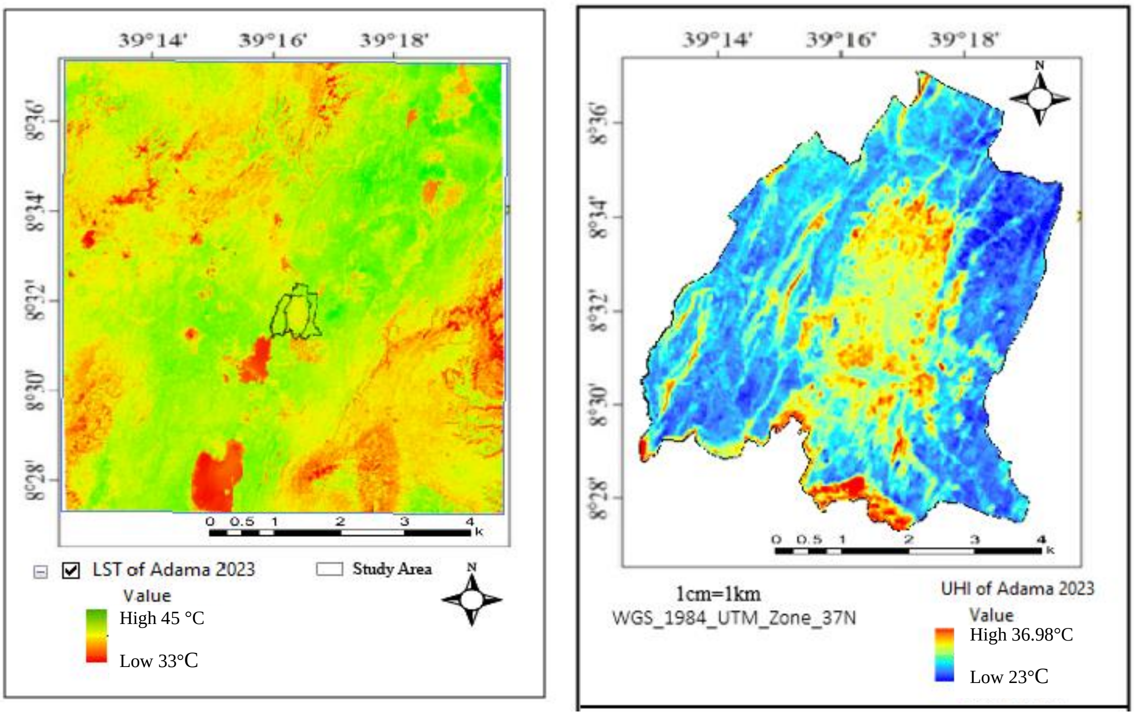


Figure 4.2 Land Surface Temperature of Adama Woreda

4.2.2 The Intensity of urban heat islands

To define the differences in urban heat island intensity within ten years (2013-2023), the difference between the temperature of each grid and the average temperature of rural areas, which is chosen in two directions, is used as the measurements.

The results showed that the minimum and maximum values of UHI were increased. 33 °C and 40 °C in 2013 to 23.7 °C and 36.9 °C in 2023, respectively in figure 4.4. The underlying factor behind the observed changes was the replacement of green spaces with impervious surfaces.

From this result, we can conclude that the highest UHI values are observed where there are many complex buildings and non-reflective areas are a large amount of temperature. Similar findings have been reported in Delhi City (Mallick, 2008).

According to Burgan and Hartford (1993), the negative values are indicative of water, snow, clouds, non-reflective surface, and other non-vegetated areas, while positive values express reflective surfaces such as vegetated areas.

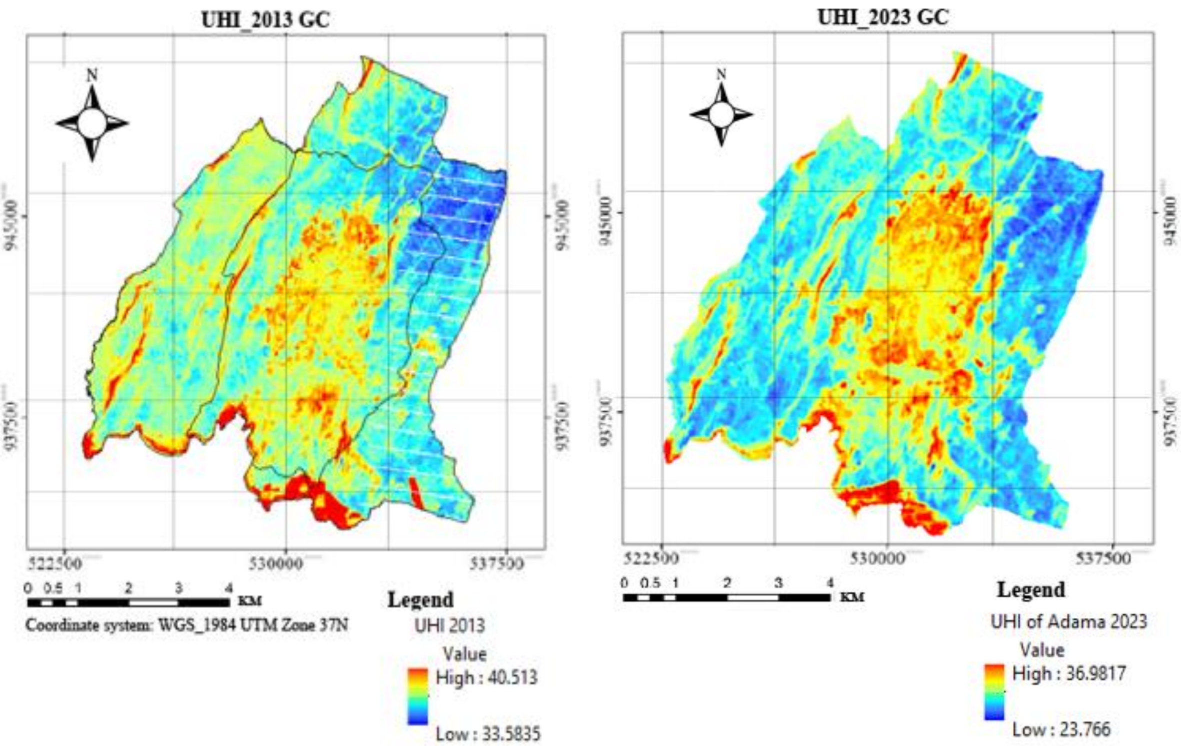


Figure 4.3 Urban heat intensity of Adama City in 2013 (Left) and in 2023 (Right).

The UHI intensity of Adama City in **2013** is:

- Urban max = 40°C
- Rural max = 33°C
- UHI = (40-33) °C = 7°C

Daytime UHI shows a seven °C of difference between urban and rural areas.

The UHI intensity of Adama City in **2023** is:

- Urban max = 36 °C
- Rural max = 23.7°C
- UHI = (36-24) °C = 12°C, Thermal comfort standard max 27^{0}c.

Therefore, daytime Adama surface UHI indicates the temperature of Adama decreased after ten years 5^{0}c. It means that from 2013 forward, there will be a higher intensity of UHI. But still urban heat island is existing in the downtown of the city in 2023.

4.2.3 Spatial Variation of land surface temperature (LST).

The spatial distribution of LST of the study area was extracted and quantified using Landsat OLI/TIRS of 2013 and 2023 data employing the thermal bands using the techniques and procedures presented in the methods chapter. The analysis from such an image indicated that the LST value of the study time ranges from 33°C. In 2013 the highest LST was 41 °C, and in 2023 it was 36.5 °C for the same period.

As was observed from the processed thermal images, the East, Northeast, and South-East parts of the study area exhibited relatively high temperatures because it has a highly developed constriction area, built density area, and barren and bare land covers and according to Jalan, (2014) reported these surfaces emitted more heat than other surfaces. Results show that LST increases with the decrease of elevation across the city and with less vegetation cover. An earlier study in Iran supports this analysis.

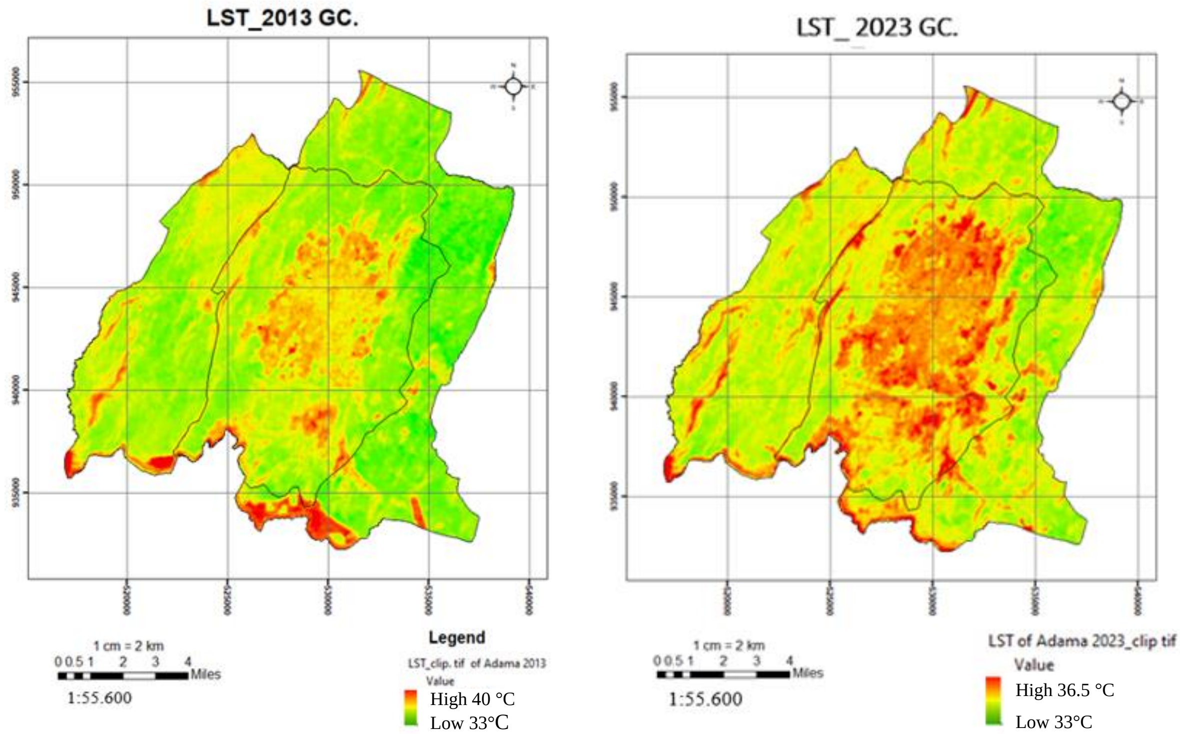


Figure 4.4 Map of LST over Adama city in 2013 (left side) and 2023 (right side)

4.2.4 Normalized Difference Vegetation Index (NDVI) Analysis of 2013 and 2023

In this study, it has been observed that the vegetation health is good, and its cover increased more in 2023 compared to 2013 coverage. The middle of the city is still a red color in both years, which means that the low NDVI area is shown in Figure 4.6.

The maximum cover of the vegetation in the cover year 2023 was 0.5, and in the year 2013 was 0.49, which shows the northern, northeastern part of the study area resulted in a higher NDVI value (Balew & Korme, 2020).

Table 4.2 Comparisons of NDVI in the year 2013 and 2023

Year	Min	Max	Mean
2013/01/01	-0.18	0.49	0.31
2023/01/01	0.17	0.50	0.33

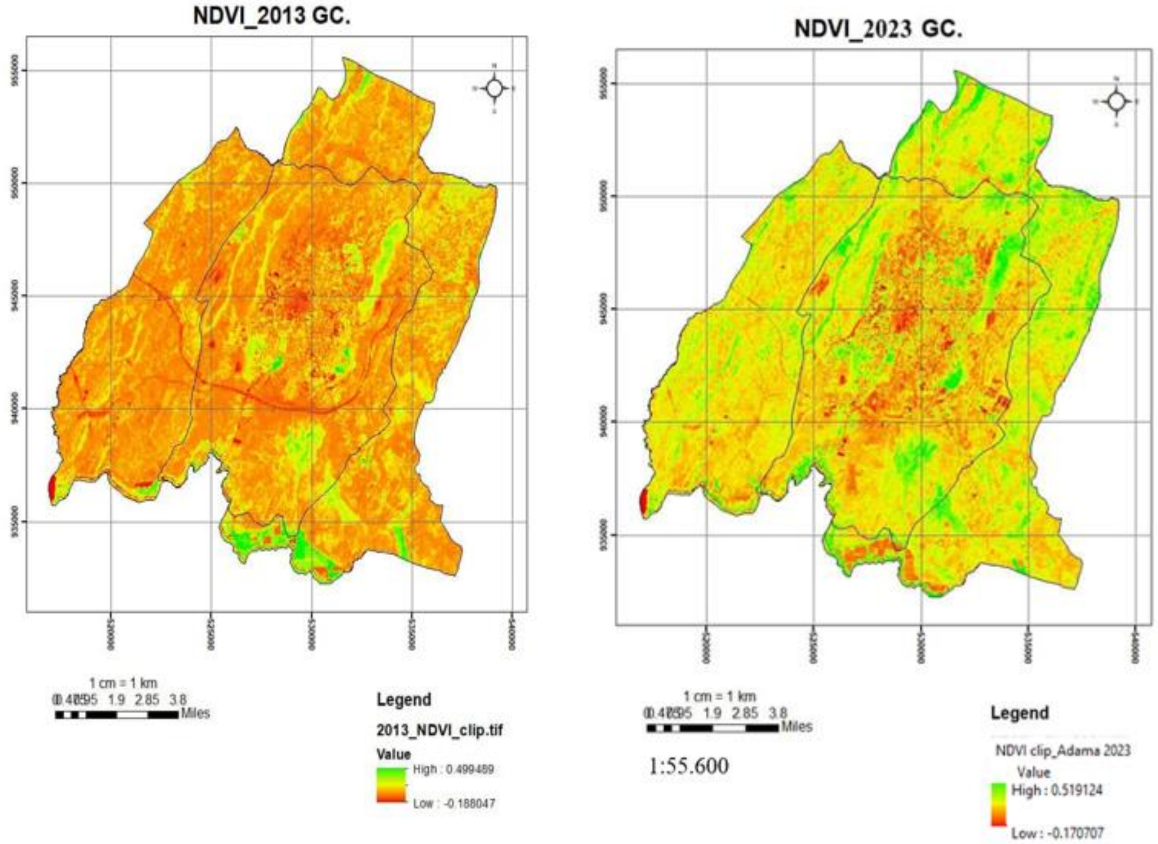


Figure 4.5 NDVI over Adama city in 2013 (left side) and 2023 (right side)

4.2.5 Relationship between Land Surface Temperature (LST) and NDVI

The graph shows that LST and NDVI are inversely related to each other. This means with NDVI increase from left to right, the Scattering of LST also increases (the value of LST is low). This result is shown in both years, i.e.2013 and 2023. This result supports the conclusion that the higher the NDVI, the lower the LST, and vice versa (Balew & Korme, 2020). A similar study was performed for the negative correlation between NDVI and LST.

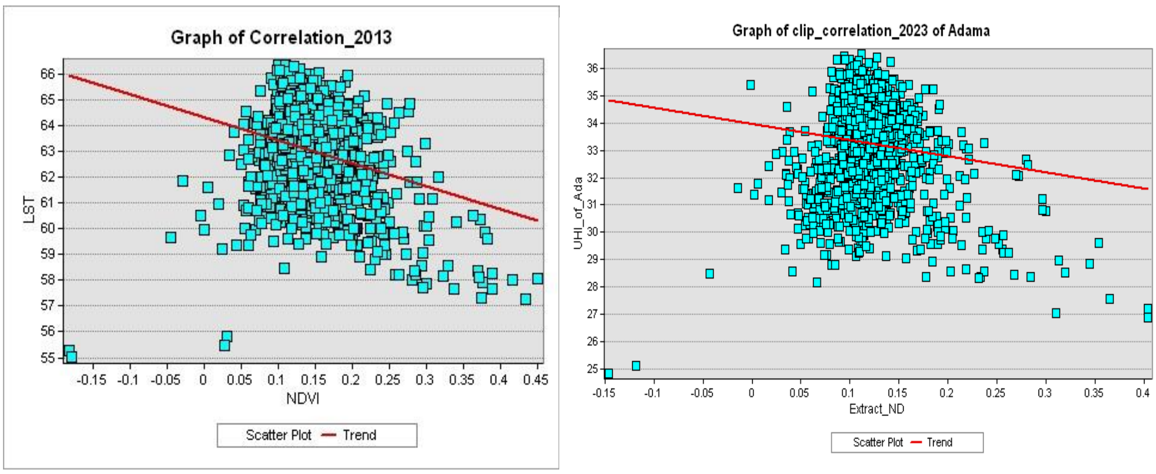


Figure 4.6 Correlations between LST and NDVI index of 2013 and 2023.

4.2.6 Land Use Land Cover (LU/LC) Change of Adama City

Urban thermal environments are determined by LU/LC variations. Among land uses, vegetation cover, open and green spaces, and enclosed areas play an important role in urban temperature. For comparison, the survey area was divided into urban areas, vegetation, agricultural land, vacant land, and vacant land.

Table 4:3 LU/LC during the years 2013 and 2023

		2013		2023	
No	**LU/LC types**	**Area(Ha)**	**Area %**	**Area(Ha)**	**Area %**
1	Agriculture	4750	36.21	4228	31.47
2	Built up	4329	32.19	5926	44.11
3	Bare land	1022	7.6	573.0	4.26
4	Shrub and bushes	1429	10.62	1235	9.19
5	Hilly area	1796	13.35	1484	11.04
Grand Total		**13,446**	**100%**	**13,446**	**100%**

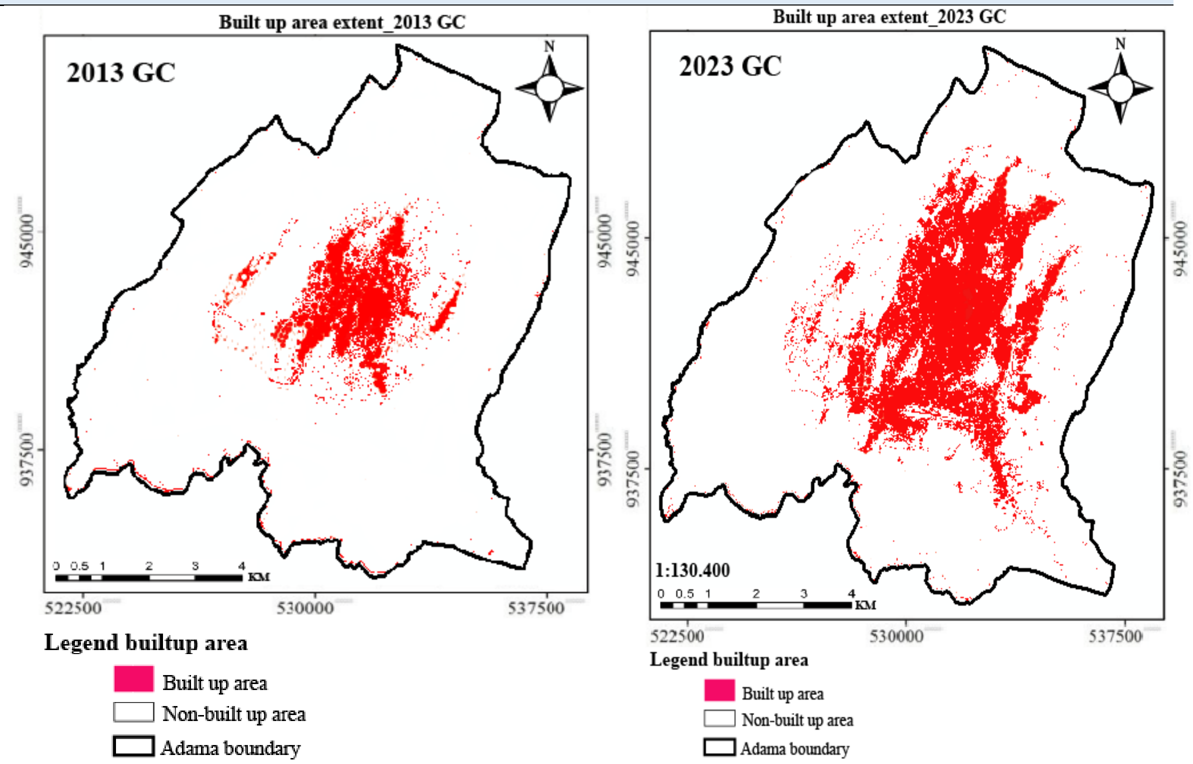


Figure 4.7 Map of Built-up area in Adama City in 2013 (left) and 2023 (right)

Among these LU/LCs, agricultural land is the most important land use class covering 13,446 hectares, followed by the built-up area, which was 4329 ha in 2013 and 5926 ha in 2023. This indicates that construction development is increasing 2023 by 13%. This result is Similar to other studies that show increases in urbanization caused by increasing trends of LST (Kifle, 2003).

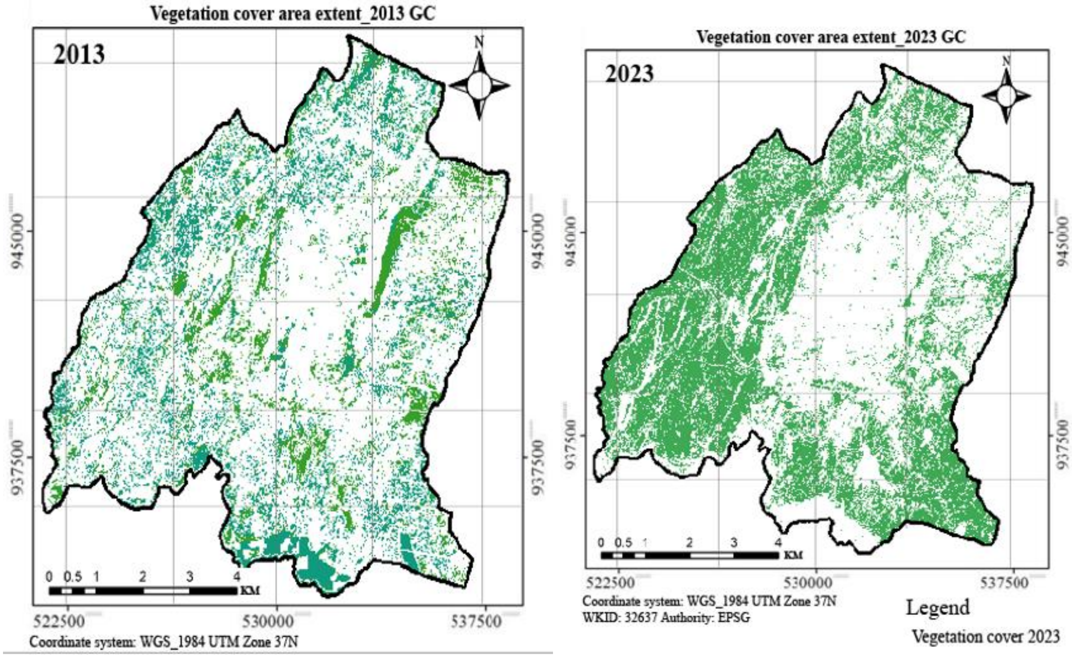


Figure 4.8 Map of vegetation cover in Adama City in 2013 (left) and in 2023 (right)

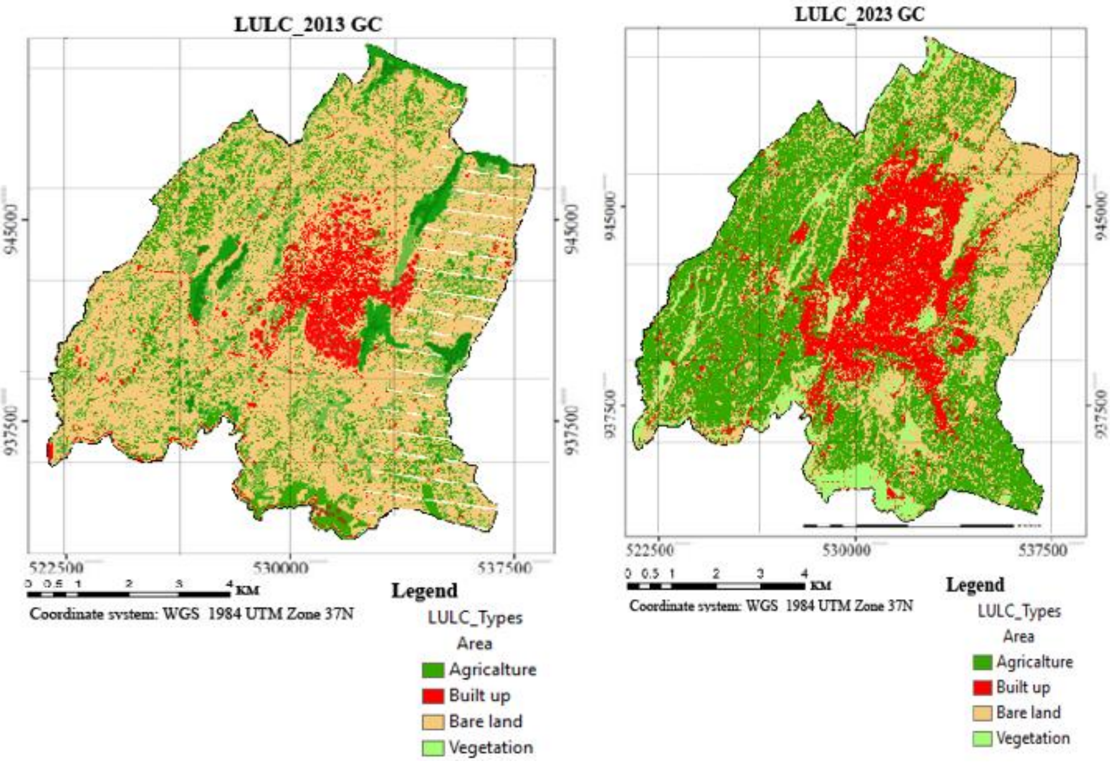


Figure 4.9 LULC of Adama city in 2013 (left) and 2023 (right).

This data shows us the interpretation of which is in the period between 2013 and 2023, built area, showed incremental changes by +1597 ha respectively. At the same time, shrubs and bare land decreased by -194 and -649 ha. This confirms that the maximum UHI occurs because of the increasing built-up area. In addition,

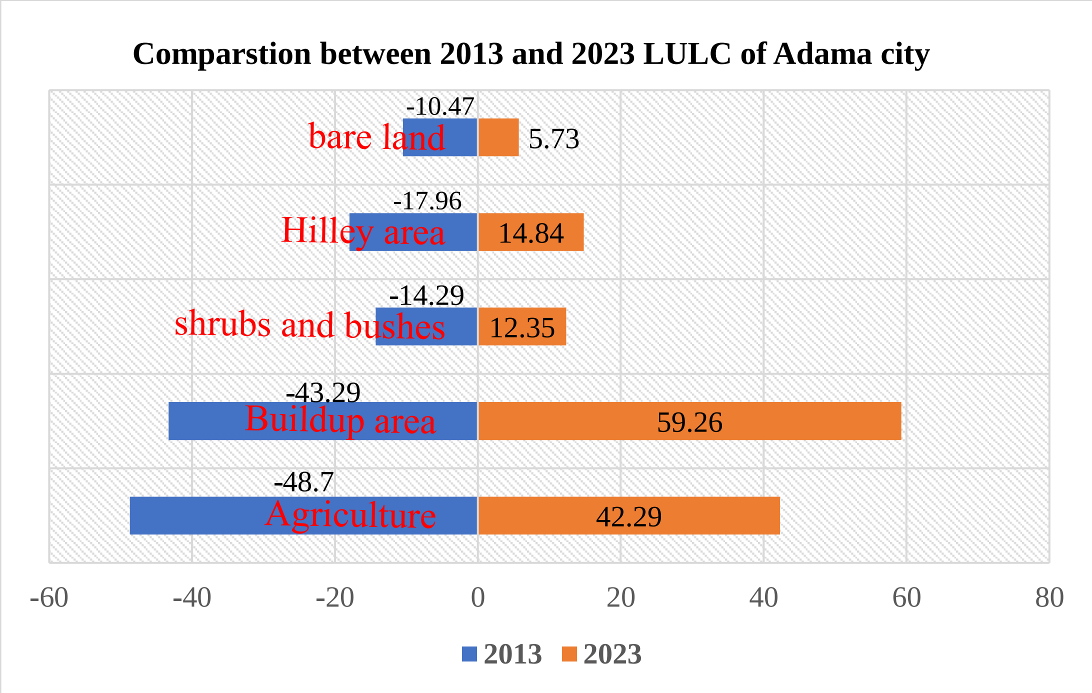


Figure 4.10 LULC Change analysis for ten years in Adama City

4.3 Computing the Temperature by Traverse.

4.3.1 Mobile survey

The selected traverse for computing the urban heat island magnitude was east to west traverse. And north to south, as illustrated below.

4.3.2 Temperature traverse East to West (E-W)

Figure 4.11 Google Earth map of Adama, which shows **East** to **West** traverse.

Table 4.4 Temperature recorded during sunny day traverses from East to West in Adama

Points	**Measuring time**	**Temp. (^{0}C)**	**Location points**		**Land use/activity**
			Lat.	Long.	
1	6:30	26	8.5^{0}49224°	39.250454°	Forest/Girar
2	6:40	28	8.548 238°	39.252742°	Pure residential
3	6:44	30	8.547581°	39.254560°	residence
4	6:46	31	8.546252°	39.257442°	Mixed-use
5	6:49	32	8.545318°	39.259758°	commercial
6	6:51	33	8.543949°	39.263111°	commercial
7	6:54	36	8.542054°	39.267510°	commercial
8	7:15	35	8.541450°	39.269012°	commercial
9	7:18	36	8.542051°	39.272004°	commercial
10	7:32	36	8.543073°	39.275919°	commercial
11	7:35	35	8.542779°	39.279199°	commercial
12	7:39	34	8.542194°	39.284869°	commercial
13	7:43	33	8.541575°	39.289617°	commercial
14	7:48	33	8.540766°	39.290824°	Mixed-use
15	7:53	32	8.539830°	39.291748°	Mixed-use
16	7:56	32	8.539088°	39.292305°	Mixed-use
17	8:01	31	8.537072°	39.294372°	Residential
18	8:10	29	8.538013°	39.297249°	Residential
19	8:15	28	8.539346°	39.300843°	Dispersed residential
20	8:25	27	8.540583°	39.303292°	Dispersed residential

(Source: from field survey by a researcher, 2023)

The graphical illustration of Figure 4.12 is displayed below. The graph clearly shows. The difference in magnitude of urban heat islands at different points in the computed traverse. The urban area marked in the study region consists of dense and complex built-up. The building materials play a major role in this temperature difference between urban and non-urban areas. (Jalan, 2014).

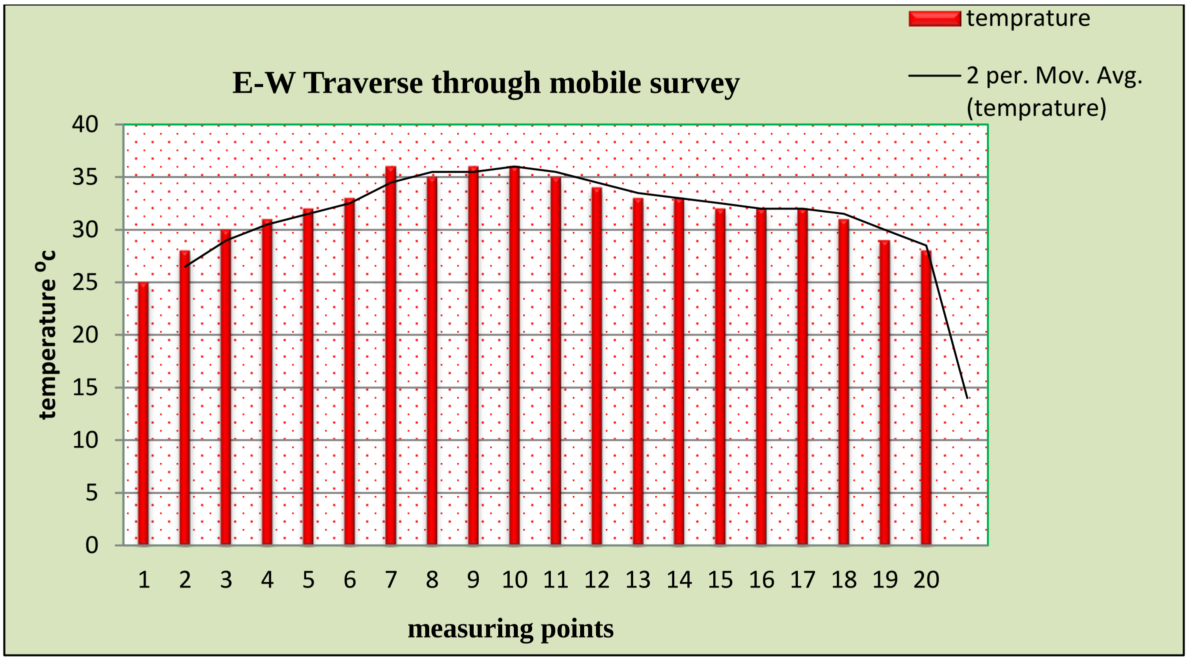
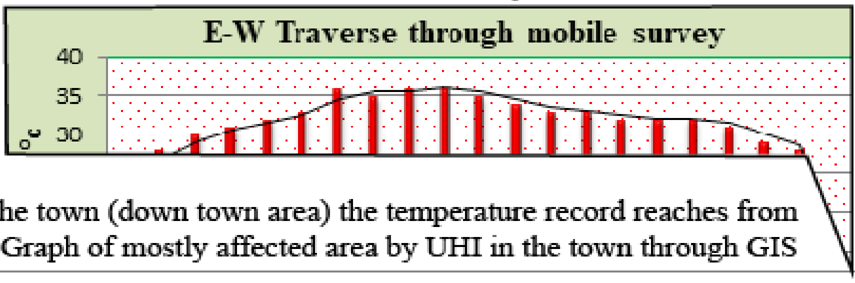


Figure 4.12 clearly shows the difference in magnitude of urban heat islands at different points in the computed traverse

Corelation with Mobile suvey and GIS



At the core of the town (down town area) the temperature record reaches from 29 °C to 36 °C. Graph of mostly affected area by UHI in the town through GIS

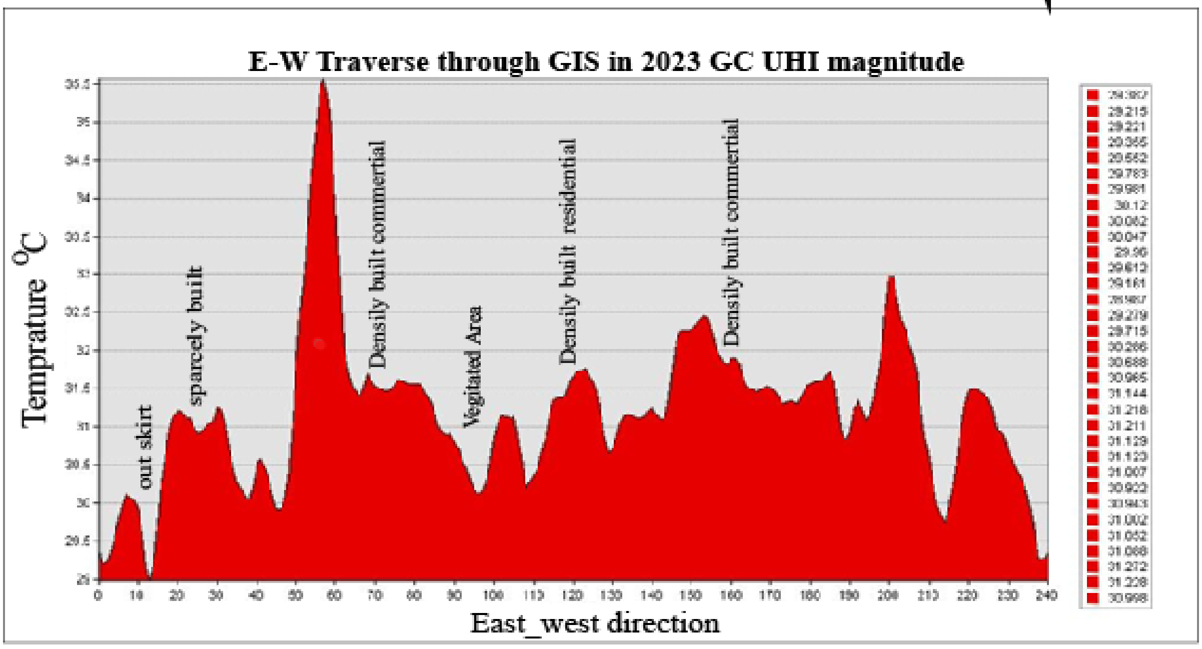


Figure 4:13 Land use map of Adama, which shows east-to-west traverse

Along the first traverse (east-west), at the initial point of the traverse, which is at the outskirt of the town and characterized by a densely vegetated area and covered by greenery, the recorded temperature was 25 ^{o}c. The next point is around a dispersed residential area, and the temperature reaches 28^{o}c. In the mixed residential areas, the temperature records 30^{o}c-32^{o}c; in this area, the amount of built-up surface (the density of settlement) increases, and inversely the amount of vegetation cover decreases. As a result, the magnitude of the urban heat island reaches 4^{o}c.

At the core of the town (downtown area), the temperature record reaches from 34^{o}c-36^{o}c. In this area, the building density is increased, impervious materials (buildings and pavements) cover the area, and the amount of vegetation is very few and sparsely exists. The magnitude of UHI reaches 5^{o}c up to 7.5^{o}c.

The heating from rural areas to downtown commercial buildings is pronounced, which may be related to changes in urban morphology. UHI reached its highest value in the city center (7.5 °C), corresponding with the location of the commercial buildings. Moving forward, the magnitude of UHI just started to decrease when the traverse passed the residential land area to the town periphery and extended to rural sites with more open areas and vegetation.

4.3.3 Temperature traverse South to North (S-N)

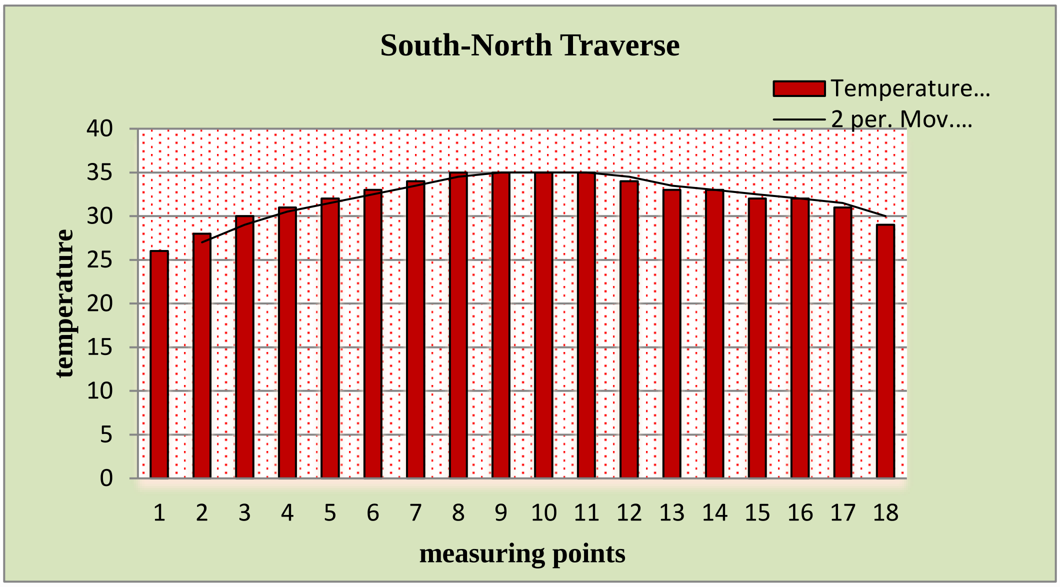
Figure 4.14 Google Earth map of Adama, which shows south to north traverse.

Table 4.5 Temperature recorded during sunny day traverses from South to north in Adama

Points	Measuring time	Temp. (^{0}C)	Location points		Land use/activity
			Lat.	Long.	
1	6:25	26^{o}c	8.560432^0	39.281148^0	Dispersed residential
2	6:36	28^{o}c	8.557826^0	39.279916^0	Pure residential
3	6:45	30^{o}c	8.552863^0	39.278123^0	residence
4	6:51	31^{o}c	8.545027^0	39.275052^0	Mixed-use
5	6:55	32^{o}c	8.541525^0	39.268967^0	Mixed-use
6	7:00	33^{o}c	8.540756^0	39.285306^0	Mixed-use
7	7:05	34^{o}c	8.539944^0	39.263951^0	commercial
8	7:15	35^{o}c	8.539656^0	39.263951^0	commercial
9	7:18	35^{o}c	8.538758^0	39.258639^0	commercial
10	7:32	35^{o}c	8.537893^0	39.254885^0	commercial
11	7:35	35^{o}c	8.532613^0	39.253465^0	commercial
12	7:39	34^{o}c	8.532477^0	39.253132^0	commercial
13	7:43	33^{o}c	8.528121^0	39.249539^0	commercial
14	7:47	33^{o}c	8.525669^0	39.248126^0	Mixed-use
15	7:54	32^{o}c	8.517613^0	39.252681^0	Mixed-use
16	7:55	32^{o}c	8.505955^0	39.247125^0	Residential
17	8:00	31^{o}c	8.504552^0	39.245998^0	Residential
18	8:10	29^{o}c	8.498657^0	39.243813^0	Dispersed residential
19	6:25	26^{o}c	8.487249^0	39237982^0	Dispersed residential
20	6:36	28^{o}c	8.483090^0	39.236538^0	Pure residential

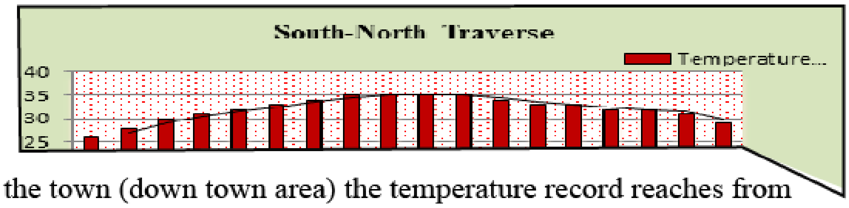
(Source: from field survey by a researcher, 2023)

The graphical illustration of the table. 4.5 was displayed below. The graph clearly shows The difference in magnitude of urban heat islands at different points in the computed traverse.



The North-South traverse figure. 4:15 showed a similar pattern to the east-west crossing above, although similar in magnitude. The highest value was 6° C, also found in a commercial building. Tree-strewn residential areas had temperatures below 3°C, followed by suburban areas at the end of the traverse. There, denser trees and less artificial land cover were associated with cooler temperatures.

Corelation with Mobile suvey and GIS



At the core of the town (down town area) the temperature record reaches from 28 °C. Graph of mostly affected area by UHI in the town through GIS.

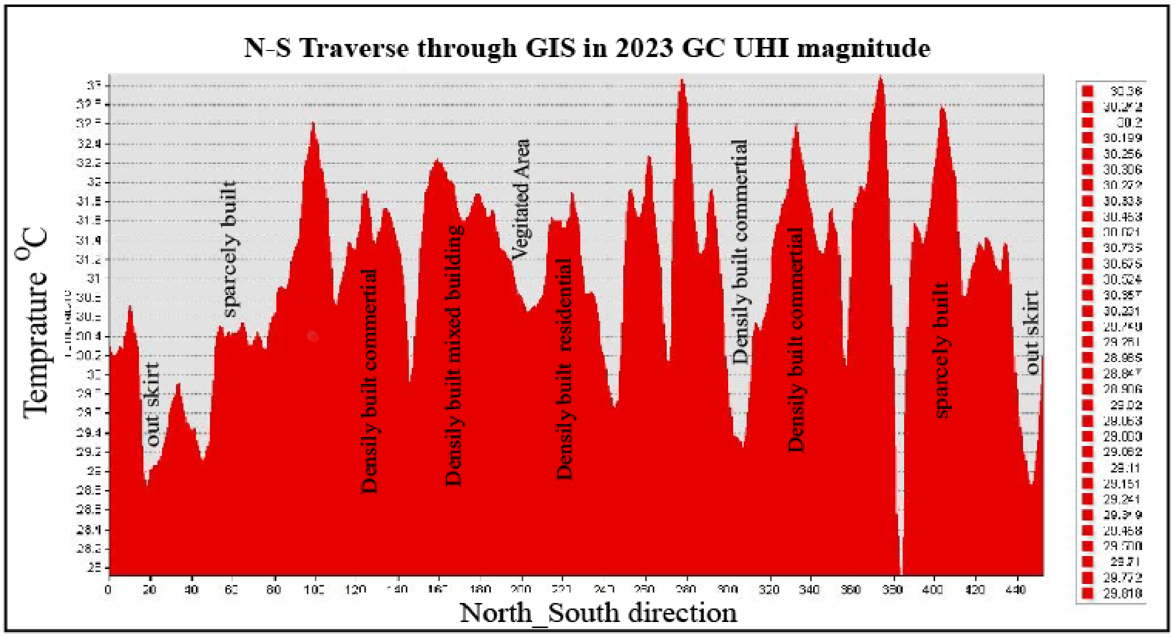


Figure 4:15 South-north traverse graph of UHI magnitude

4.4 Urban morphology, land cover, and UHI magnitude

It has already been shown to significantly alter natural surface conditions and atmospheric properties, which can lead to different warming patterns within urban areas. Furthermore, there is a strong relationship between land cover and temperature, especially between vegetation and built-up density, suggesting that different types of land cover within a city may influence the spatial pattern of its UHI.

4.4.1 Urban Morphology

Normally, the temperature distribution depends on the layout of the city. The urban heat island is characterized by a high-temperature gradient at the urban-rural boundary followed by a gradual increase in temperature towards the urban center. The closer the area is to the city center (higher building density, commercial area, less vegetation). At higher temperatures between 34 °C and 36 °C. The further away an area is from the city center (fewer buildings and more vegetation), the colder the temperature. Urban morphology and impermeable land cover are important for the formation of UHI in cities. By analyzing the urban temperature profile, we were able to examine the role of building density in increasing UHI values up to 6^{o}c in densely built-up areas when we compare them with the periphery of the town.

4.4.2 Vegetation Cover

Vegetation is directly related to lower temperatures. Although the extent of urban heat islands is small, they are identified in densely vegetated areas; according to traverse data, the temperature in densely vegetated areas ranges from 26^{o}c up to 28^{o}c. This shows that the magnitude of urban heat islands is related to vegetation cover. The effects of surface benefit on lowering the town temperatures are notable, especially when crossing. Vegetated areas.

4.4.3 Urban land covers / Impervious Surfaces /

Impervious materials in urban areas, like buildings and pavements, were directly related to the intensity of urban heat islands. These materials are brick, asphalt, and concrete, and they do not reflect the sunlight (low albedo materials) but absorb the heat and increase the temperature in the town. The thermal reflectivity of the material ranges from high albedo (1.00) to low albedo (0.0). The reflectivity of asphalt ranges from 0.05-0.20, brick 0.20-0.40 (low albedo materials), and white paint have a reflectivity of 0.5-0.9 (high albedo). The property of construction material has a greater role in urban heat island formation in urban areas.

4.5 Mapping urban heat island profile for Adama City

Depending on the above traverse data, the graph of the urban heat island profile for Adama City is mapped. The graph shows the relationship between urban land uses (impervious urban land cover) across the town versus temperature difference (the magnitude of urban heat island) throughout the town.

Table 4:6 Mapping urban heat island of Adama

No	Physical characteristics of places	Description
1	 outskirts of the town	The area was mostly covered by forest (different types of greeneries and vegetation cover), and the temperature was from 26°c to 27.5°c, which is low in the magnitude of UHI.
2	 Sparsely built settlement areas	The area was characterized by less built-up density. This area was an expansion area within the town. And the temperature ranges from 28°c to 30°c.
3	 Vegetated areas in the town	Within the town, there are places of built environments with high coverage of vegetation. In these places, the temperature fluctuates down to the range of 27°c up to 29°c.

4	 Densely built residential areas	In a densely built area which is characterized by very little vegetation cover, and amount of built-up area is increased. In this area, the temperature started to rise and reached 31°c up to 33°c. From this, we can justify that as the built-up surface increases, the magnitude of urban heat islands increases.
5	 Commercial areas	Commercial areas with the densely built-up area and the amount of impervious material increased; buildings in this area vary in their story, and also the surface was paved by different types of materials and less amount of vegetation coverage. In this area, the temperature reaches 34°c up to 36.7 °c. At this point, the temperature of the town reaches the pick point, and the magnitude of the heat island is also 5°c to 7.5°c.

From this, we can summarize that the magnitude of urban heat islands is fluctuated from place to place in the town and is related to urban morphology, vegetation covers, and impervious surface. The graph of the Adama urban heat island profile is shown below:

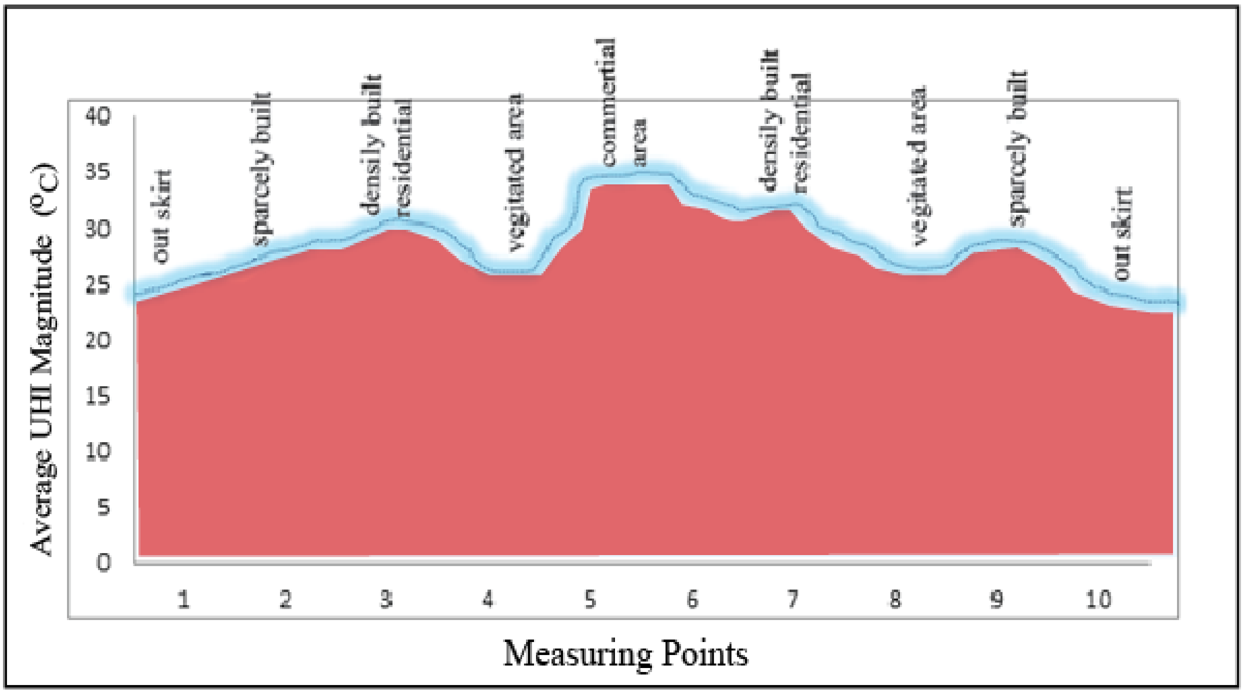


Figure 4.16 Typical UHI profile of Adama City (Source: computed by Researcher from the summary of the traverse, 2023)

4.5.1 Mostly Affected Area by UHI in the Town

According to data gathered from the traverse of east-west and north-south on clear and sunny days, the magnitude of urban heat island increases (5^{o}c – 7.5^{o}c) when we move from a suburb area to a downtown area, and as well as the land use also changes from densely vegetated areas to different urban land uses and structures.

From the above analysis, I identify that the urban heat island effect is higher in the core or downtown area of Adama, which is characterized by densely built areas, high commercial activity, and sparse vegetation cover. In general, the area is covered almost by buildings and different structures.

4.5.2 Analysis of the Effect of the urban heat island

Gender of Respondents

From selected respondents according to sample size, the male was 130, which covers 65.3 %, and as female was 69, which is 34.7 % of the total respondents of 199 people. From those, the number of participants who agrees with the issue and respond to the questions and give available data is 192 people, and seven people ignore the issue.

Table:4.7 Respondent's response on **the effect of the urban heat island.**

No	Issue	Responses
1	Is there any temperature difference in the town?	(96.5%) Yes, there is a temperature difference in the town. In the winter seasons, it is very hot, and in recent times it has increased in its magnitude.
2	In which area is it mostly exposed in the town?	The intensity of urban heat islands is higher in the downtown area rather than in dispersed residential areas and outskirts.
3	Problem-related to the increase in downtown area temperature?	In the winter seasons, it is difficult to work as well as to live walking in the street on a sunny and harsh day which affects the comfort of residents.
4	The measure was taken by dwellers.	In commercial buildings, they use ventilators, and as well as they stop working and take rest during temperature rise in harsh time to overcome the problem of hotter temperature.

4.6 Results of Responses from Respondent

According to data gathered from the respondents through interviews, there has been a temperature difference in Adama City in recent years. This temperature difference was mostly occurring in the winter seasons, a season which was known as dry, sunny, and hotter than other seasons. The effect is mostly occurring in downtown areas rather than in dispersed residential areas and as well at the periphery of the town. The other is the building material, also a great influence thing according to respondents living in houses and offices constructed from concrete and aluminum (for buildings mostly exposed to direct sunlight) have very difficulty during the day for work and at night, which results in the increment of temperature in the houses which cause discomfort.

To overcome the effect, mostly in the daytime in commercial activity areas and around offices, peoples use ventilators to cool down the temperature of the room. This measure is also another problem in terms of increased energy consumption and also causes people to pay extra expenses.

The other thing is related to comfort in the day, mostly in the downtown area; according to respondents, there is very difficult to walk and work in a downtown area, mostly in the winter seasons, because the air temperature of the area is very increased.

4.7 Problems related to the increment in temperature

Temperature rise because of different problems related to environmental degradation and public health. According to data from the Adama General Hospital, temperature rise-related diseases increased from time to time. Those diseases were mostly related to the respiratory body, which was caused as a result of the rise in temperature and air pollution in urban areas. Accordingly, the effect of urban heat island rise on urban dwellers causes discomfort and affects the health of the residents.

Air pollutants generated as a result of land cover change and environmental degradation, such as particulate matter and carbon monoxide nitrogen oxides, can damage lung tissue and aggravate breathing problems, respiratory illness, and cardiovascular disease.

4.8 Site analysis for factors of UHI increments

Depending on computed temperature through traverse, the magnitude of the urban heat island varies from place to place in the town, which depends on urban land covers and other activities. Accordingly, at the place where the magnitude of the urban heat island increased action area was selected for detailed analysis.

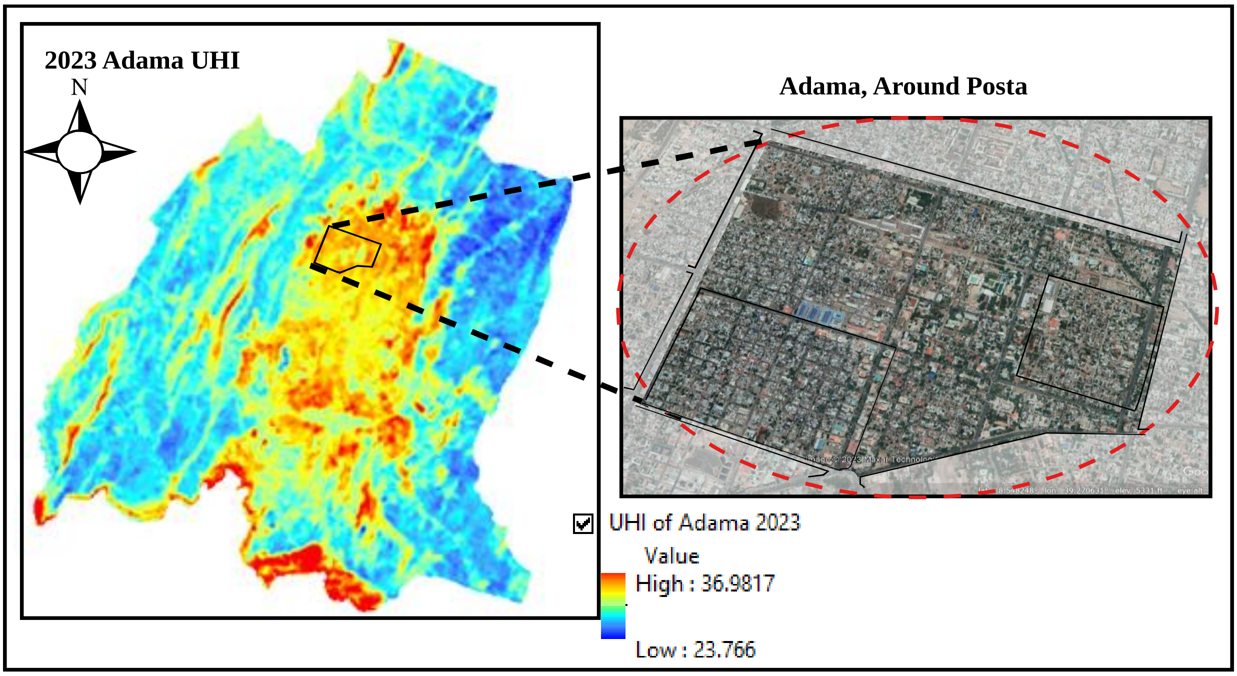


Figure 4.17 Location of a most affected selected site

4.8.1 Existing Information Site Features

The area was characterized by high commercial activities. Because of these, many people interact and exchange different goods as well a high traffic volume also exists in the area. As a result, the area was exposed to a high amount of air pollution and emission of gases, which is one of the causes of the rise of temperature in the area. The settlement of the area was characterized by densely built old settlement areas.


Figure 4.18 Characteristics of the site

4.8.2 Physical Factors of the Study Area

4.8.2.1 Land use of the area

The existing land use map of the area Figure 4.22 shows the majority of the land use coverage of the area was commercial land use category and followed by the street network, 44.1% of land use coverage, and 25.06 % is a street layout of the site, and followed by manufacturing and storage and mixed-use activity retail and mix uses 15.97% and 14.8 respectively. This is because of the location site, which is found at the center of the town, and the area is mostly concerned with commercial activity.

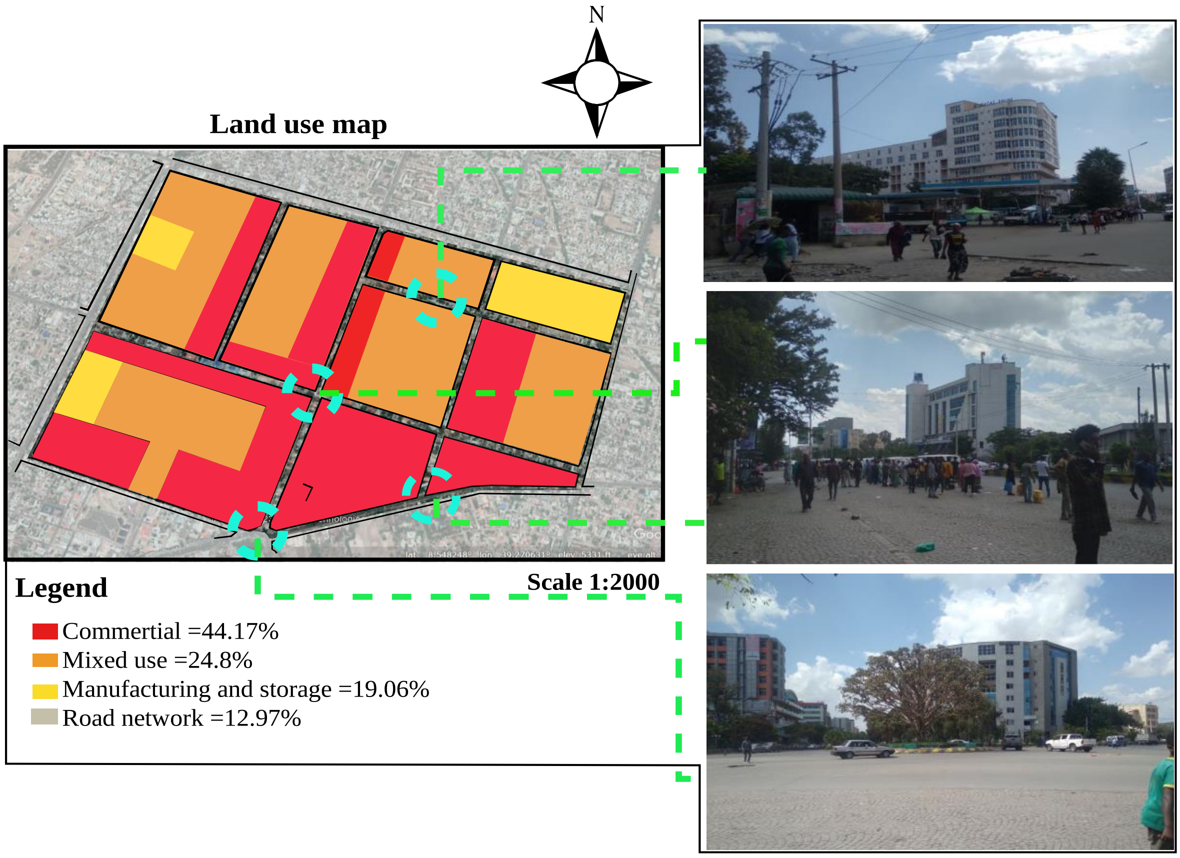


Figure 4.19 Commercial activities in the site and transport

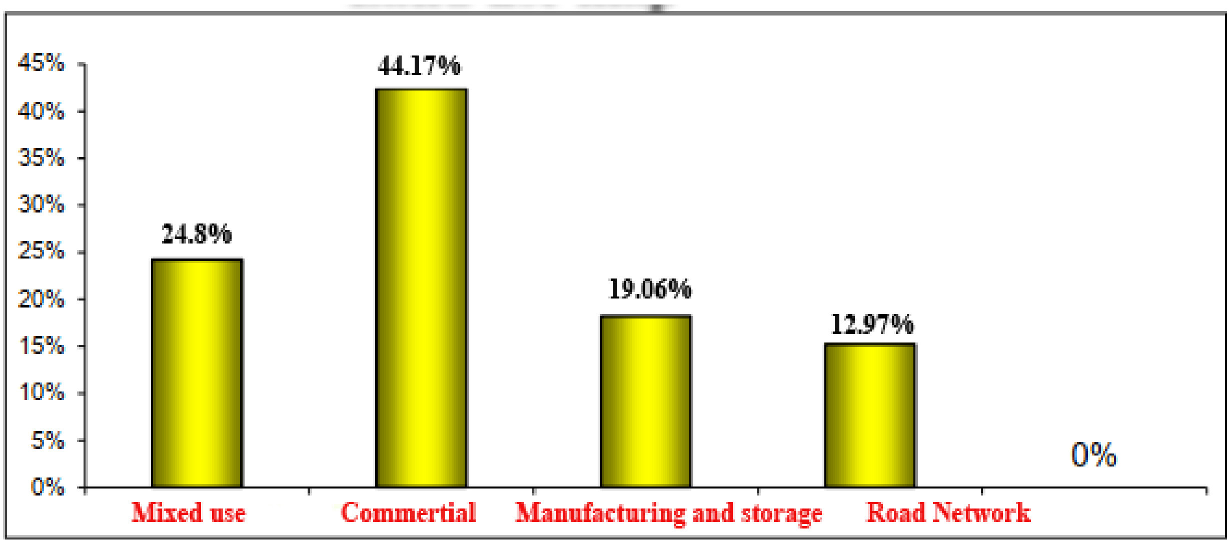


Figure 4.20 Land use map of the sit

4.8.2.2 Morphology of the Study Area

The morphology of the area was characterized by a highly built-up area According to the building density analysis in the selected site, it has more old structure and density than other areas. The site is dominated by one and two-story buildings, which means the area was mostly covered by different man-made structures or impervious structures. These impervious structures absorb sunlight.

Figure-ground analysis (Solid and void analysis) it is shown that the percentage of solid areas in the site 75% (Map 1). This shows that the hard surface areas are more than soft spaces, and it increases the climatic condition (air temperature) in the outdoor and as well as indoor spaces.

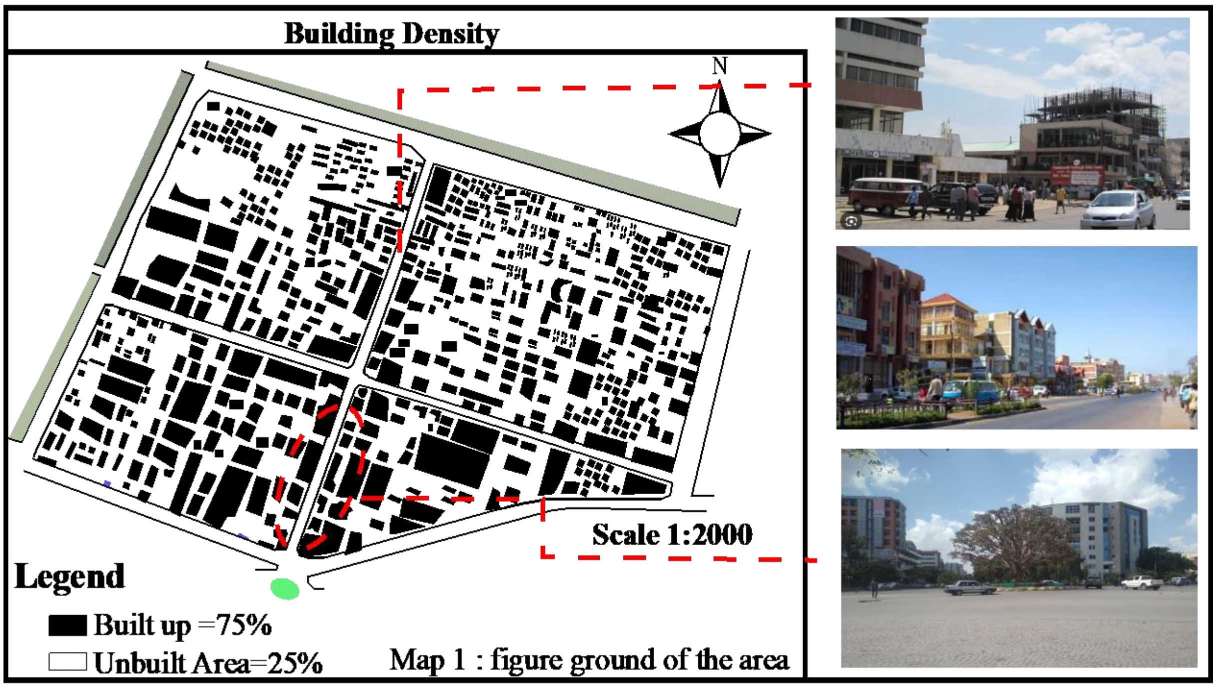


Figure 4.21 Building density of the site

4.8.2.3 Vegetation and Greenery Analysis

The area was completely covered by impervious structures, and there was not any green vegetation or green land in the area. Map 2, below, shows that there was countable (very little) vegetation exists in the area. Vegetation in urban areas has multiple benefits sustaining environmental temperature, minimizing noise, decreasing pollution by absorbing greenhouse gases, and being used as a shade for dwellers of the area.

As stated by Suszanowicz (2019), "Trees generate shading that; Reduction the penetration of solar radiation to the facade. Reduce energy usage for cooling. Decline the amount of heat coming inside the buildings to create shaded surfaces with a lower temperature. But the area was only occupied by impervious structures, and this is one factor for the increase of the urban heat island effect in the area.

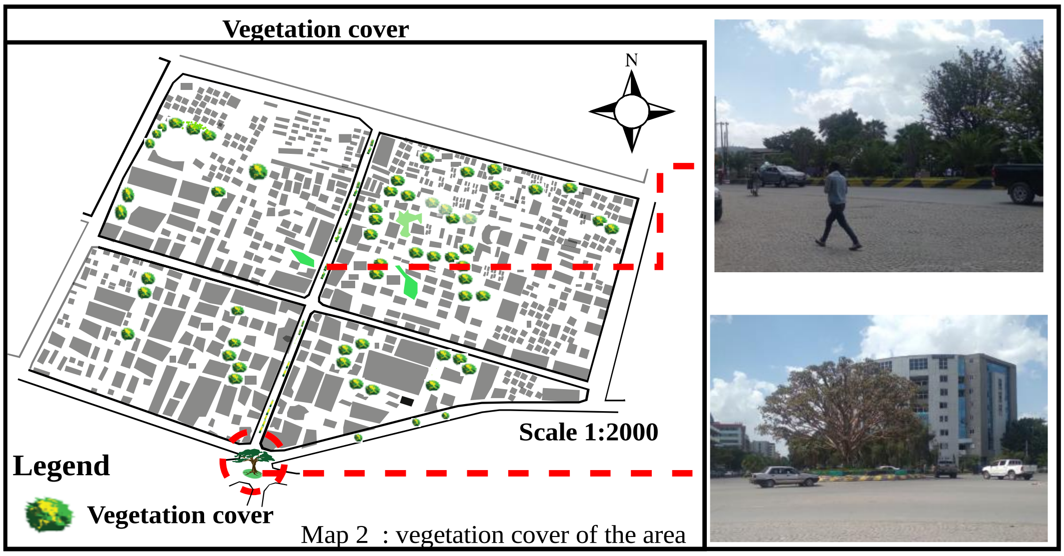


Figure 4.22 Vegetation in the site

4.8.2.4 Building Materials and their characteristics

The land cover of the action area was occupied by different structures. Those are buildings which construct from different construction materials like concrete and HCB, which have a high absorption of heat and store and release back to the environment at night time. The other land cover was asphalt pavement, also characterized by its low reflectivity of the sunlight and the same as concrete structures.

Materials like asphalt, stone, and concrete tend to keep and release heat slowly on facades. Urban temperatures have been proven to cool down by high albedo building surfaces such as white materials ((Akbari, 2001). These materials are brick, asphalt, and concrete, and as mentioned before, they do not reflect the sunlight but absorb the heat and increase the temperature in the town.

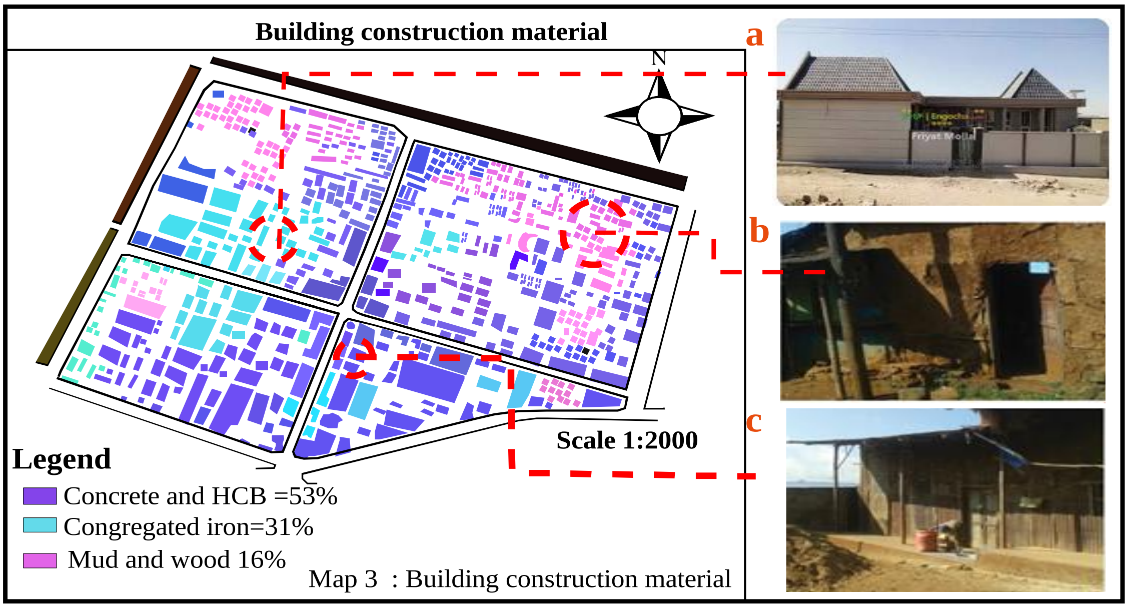


Figure 4.23 Construction material (a) concrete and HCB, (b) mud wood, (c) congregated iron sheet.

4.9 Mitigating UHIs Simulation through ENVI-met.

The boundary condition was set according to the current situation of the building model based on weather data obtained from the mobile survey. There are different types, shapes, and forms of residential and commercial buildings on the existing site. The form of the building does not affect the surroundings, but mainly the simulations focus on the building material currently which is used for the construction. From the following existing model, take one for the simulation analysis, which is constructed by Concrete heavy, HCB, and black roof.

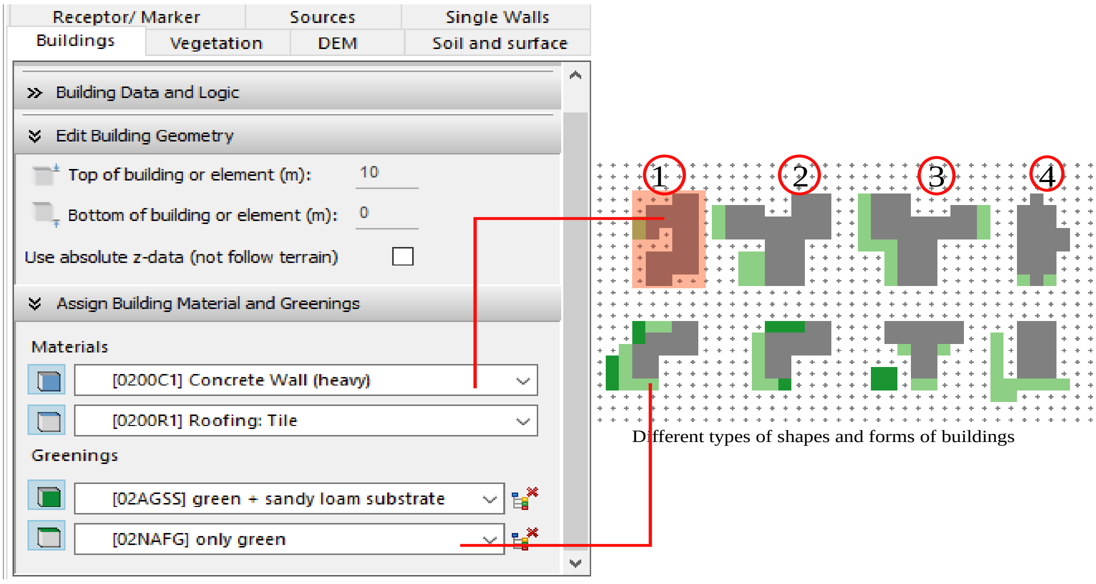


Figure 4.24. Selected Model building for Simulation

ENVI-met was employed to simulate the metrological data and nature of the city model. This simulation compares the situations of Adama building materials within three scenarios, according to the variables of the NVC model. These 3 Scenarios were created as follows.

Scenario 1: Cover the roof of the building and model area with vegetation cover;

Scenario 2: Change current low albedo material to high albedo materials: and

Scenario 3: The mix of both greenery and high-reflectance albedo material

Figure 4.25 illustrates the current situation of the model building depending on the Building materials, and three scenarios simulate in ENVI- met based on climate data obtained from the mobile survey.

Table: 4.8 Different uses of building materials in different scenarios.

The material and Albedo value used for building				
Surface	**Albedo**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Concrete	0.30	Horizontal and vertical surfaces and roofs were	00.85	Scenario 1 and Scenario 2 can compact together to minimize the
Road is Asphalt	0.14-0.16		0.55	

Clay soil	0.17-0.23	covered by vegetation cover.	0.6	effects of downtown UHI. (High Albedo material and vegetation)

According to simulations, These two scenarios show that highly albedo materials and vegetation cover can contribute to UHI mitigating separately. In 3rd scenario, the area was covered with high-light albedo materials along with vegetation cover to see how these two scenarios could have contributed together the effects of the urban heat island.

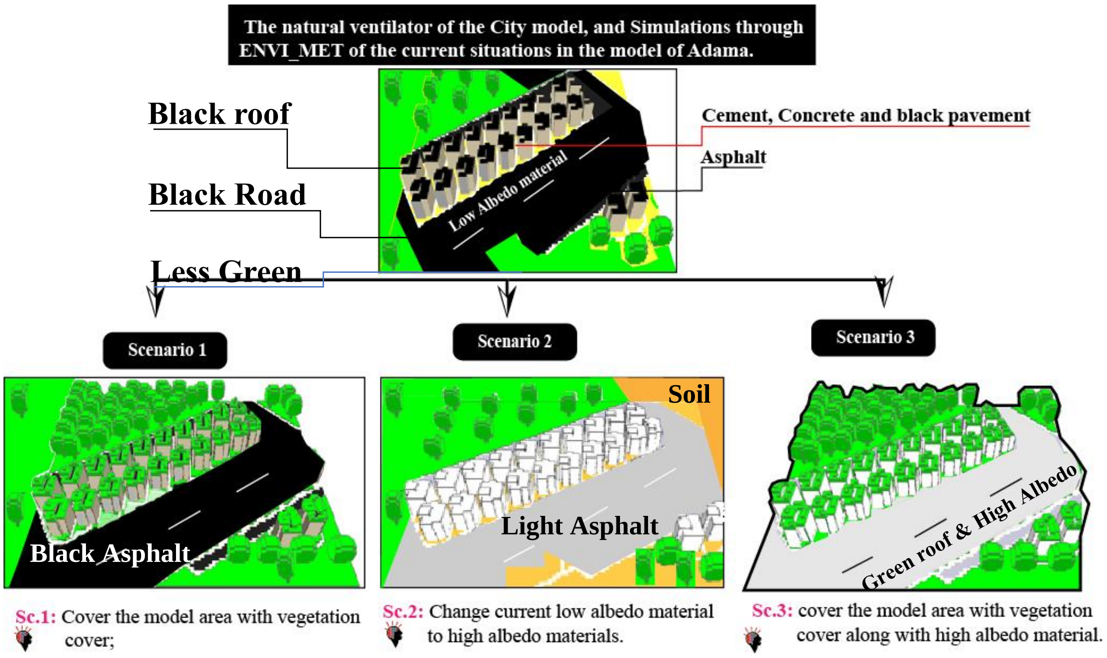


Figure 4.25 ENVI-met model area and three scenarios.

Figure 4.26 shows that the model area has a higher temperature of 308.15k (35.5^{0}c) and occurs on roads and roofs of buildings with low albedo materials as asphalts and less vegetation cover. The simulation results indicate that a green area with less temperature of 299.15k (26^{0}c) where observed.

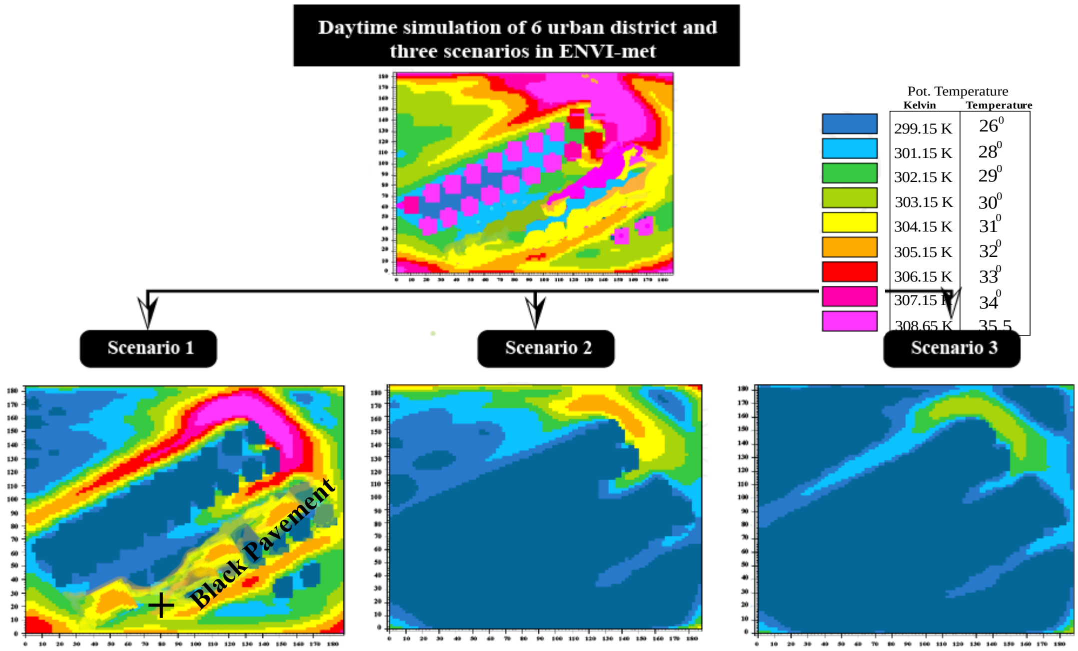


Figure 4.26 Daytime simulation and the three Scenarios through ENVI-met)

Scenario One: The areas with green roof and greenery has been reduced from around 307.15k (34^{0}c) to 299.15k (26^{0}c) to 303.15k (30^{0}c). Moisture contained in the soil does not cause temperatures to be similar to those of hard floor and pavement areas. Although the vegetation cover decreased temperature, there are still higher temperature inroads. Green roof contributes to decreasing the temperature in the housing area.

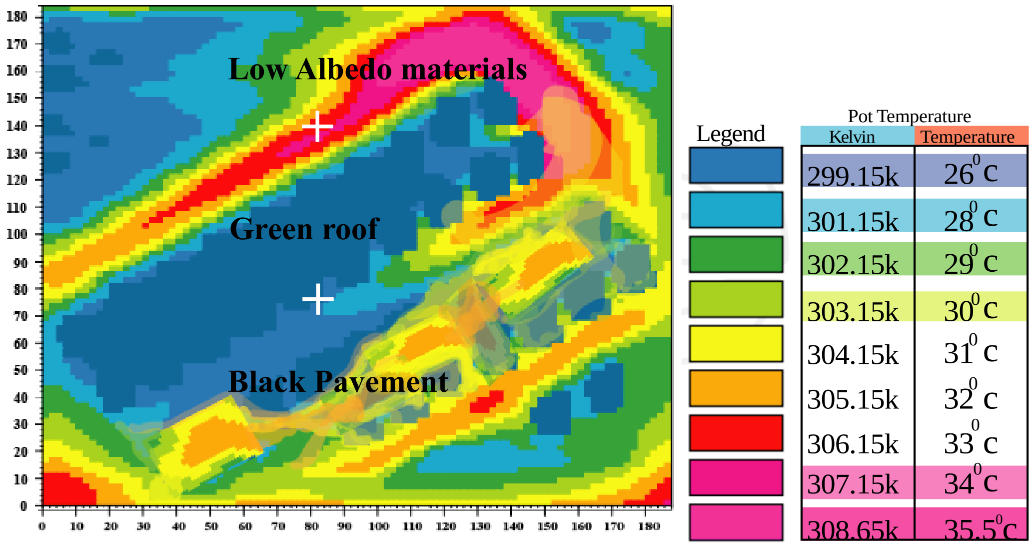


Figure 4.27. Scenario One Simulation

Scenario Two: The cooling effect of high albedo materials can be seen in simulations, decreasing between 299.15k (26^{0}c) and 301.15k (28^{0}c). Around building area less than 299.15k (27^{0}c). This shows that High albedo materials have extreme effects on decreasing Ambient temperature. While there is vegetation is replaced by hard pavements at that time, the higher temperature is 308.65k (35.5^{0}c).

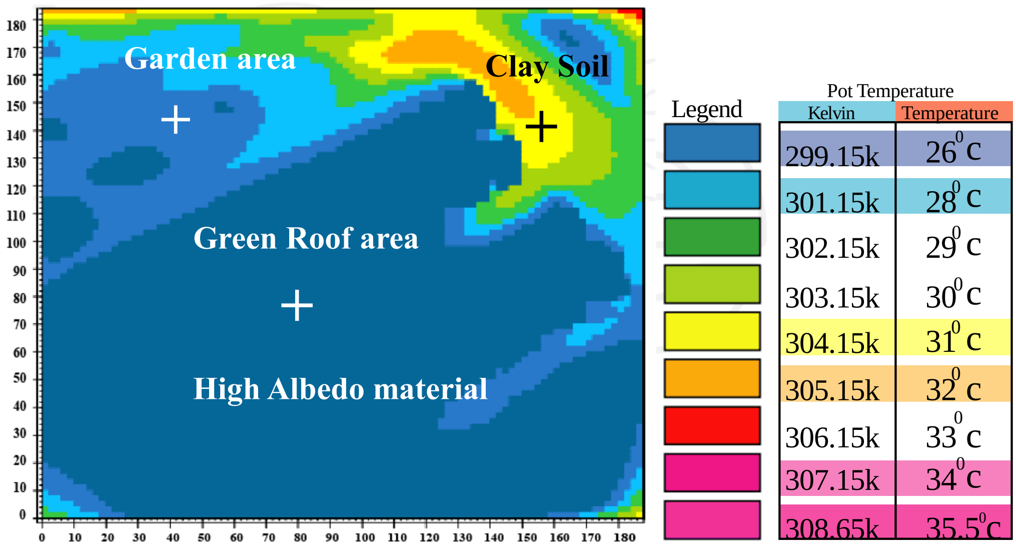


Figure 4.28. Scenario Two simulation

The redaction of downtown UHIs of the temperature in the areas with more vegetated cover and high albedo building area can reach 5^{0}c-7.5^{0}c. In the comparisons of scenarios 1 and 2 and the current situation for temperature, scenario two has more effect on the surrounding built-up area than vegetation cover.

Scenario There: It is obvious Combining these two variables, the temperature can drop to about 5.5°C. On the other hand, Scenario 3, which combines Scenarios 1 and 2, makes a significant contribution to cooling and mitigating the high temperature.

Furthermore, the qualitative analysis of temperature data indicates that the most comfortable areas were in forested or green areas, as well as around non-reflective buildings. This suggests that the presence of greenery can help to reduce temperatures, which is supported by survey measurements.

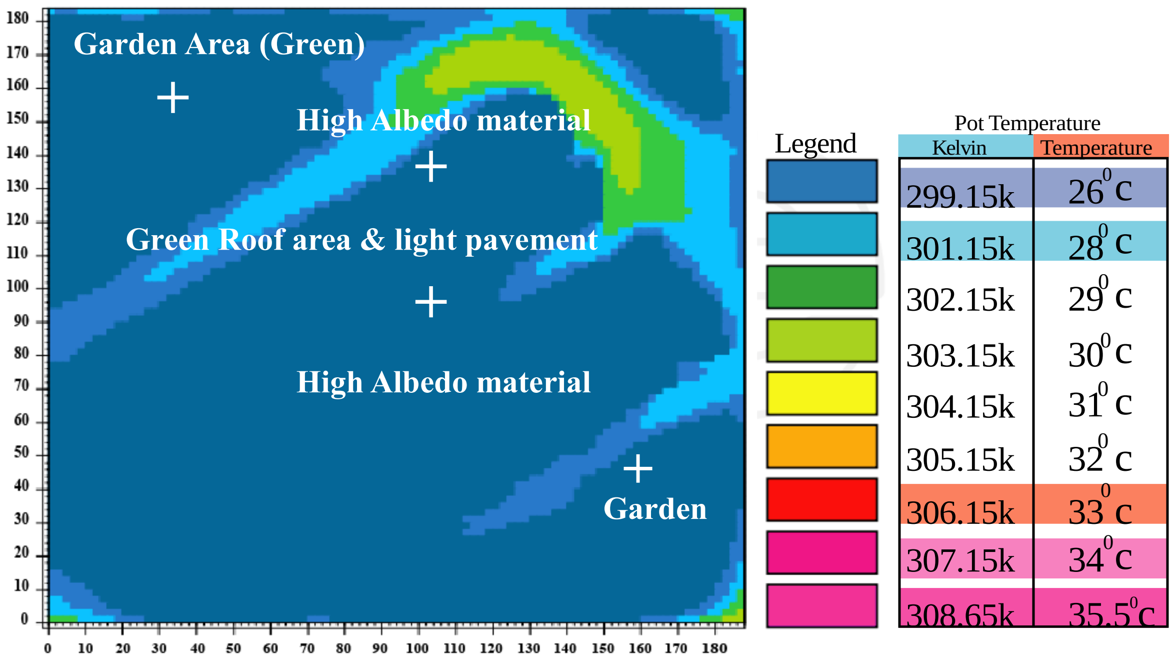


Figure 4.29. Scenario Three Simulation

Generally, As figure 4.32 shows that the comparison of the three temperature scenarios shows that Scenario 3 has the best cooling effect on the surrounding urban area and, at the same time, the green area with high albedo. Material can be confirmed by the simulation. So in any urban design and construction activity, using greenery only or using high albedo material only for urban design is not the best solution, but merging with using placing vegetation on the building, High albedo building materials, Cool roofs for flat-roof buildings and Taking into consideration building layout and orientation in the urban design process is make the best solution and comfortable our surroundings outdoor temperature.

Overall, it appears that a combination of strategies, such as incorporating greenery and implementing Scenario 3, may be effective in reducing high temperatures and creating more comfortable environments.

4.10 Major Findings

From the above analysis, the result and discussion of major findings are summarized as follows:

- ✓ The magnitude of the urban heat island in the downtown area of Adama City is $5^{o}c$ to $7.5^{o}c$ greater relative to the nearest rural areas on clear and sunny days.
- ✓ The land surface temperature depends upon the reflective conditions of the surface of the earth. In general, areas of non-vegetated and non-reflective surfaces have high LST than those of vegetated.
- ✓ The normalized Differential Vegetation Index (NDVI) Value is less for water bodies, bare land, urban area, and agricultural land classes. The Green cover of the study area has increased dramatically. This could be because of the movements like a green legacy.
- ✓ The normalized Differential Vegetation Index plays a great role in assessing and investigating LST. Land surface temperature and NDVI have indirect relationships.
- ✓ Land use change / the conversion of previous surfaces like vegetation, greenery, and grasslands by impervious structures (buildings and pavements) which have high heat storage capacity and high thermal conductivity like concrete and asphalt, etc., are key drivers for the formation of urban heat islands.
- ✓ Urban heat island is directly related to urban land covers like buildings, pavements, and as well as urban morphology. The intensity of UHI increases when the number of urban land covers (building and surface pavements) increases, and UHI decreases when the amount of vegetation and evapotranspiration surface increases.
- ✓ The magnitude of urban heat islands in the densely built-up areas increases rather than in dispersed residential neighborhoods and the outskirt of Adama city.
- ✓ Increasing the usage of low albedo material for paving as well as for different construction of the structure in the town has a high contribution to the increment of UHI.
- ✓ Urban heat island rise affects the well-being of urban dwellers by causing discomfort and affecting the health of the residents, especially in the winter season.

- ✓ The rise of temperature in a downtown area results for increase energy consumption and also causes extra expenses.

- ✓ On sunny and clear days walking in the downtown area is very difficult because of the hotter air temperature, which results in discomfort to commute along the roadside.

- ✓ Based on the information provided in ENVI_met simulation analysis, it appears that two variables are being considered: Scenario 1 and Scenario 2. It is suggested that combining these two variables can result in a temperature drop of about 5.5°C. Additionally, Scenario 3, which combines Scenarios 1 and 2, is said to make a significant contribution to cooling and mitigating high temperatures. This also creates the best comfortable outdoor environment.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

LANDSAT Satellite data with different sensors are useful for applications such as LST relation between changes and NDVI. Landsat imageries have great potential to examine the LST dynamics and vegetative and non-vegetative changes relation.

A thermal band of Landsat image was important in quantifying the land surface temperature of the area. The Reason behind Less NDVI and high LST value in the agricultural area like the Southern part (won ji sugar) is that the image was taken during the harvesting time of December. Due to this, the bare land has high surface reflectance. The land surface temperature depends upon the reflective conditions of the surface of the earth. In general, areas of non-vegetated and non-reflective surfaces have high LST than those of vegetated.

It reveals that land sat OLI 8 images are very useful in quantifying and mapping NDVI and LST Change in Adama Woreda. The NDVI pattern of the study area has been attributed to socioeconomic and natural factors and their exploitation in time and space.

The land surface temperature of Adama City indicated a Slight variation. Also, the NDVI of the study area shows an increase. The derived NDVI values from satellite data are also somehow a good indicator of the LST status of the state area.

In Adama City, the highest temperature is recorded during the winter season, which is the hotter month in the year (from January to March ranges), from 28^{o}c -30^{o}c. According to measured data from the field during sunny and clear sky days, the temperature variation of the inner city or downtown area of Adama extends from 5^{o}c to 7.5^{o}c when compared to the nearest rural and sub-urban areas.

The replacement of vegetation and open land by urban landscapes and anthropogenic activity tends to be the main factors responsible for the detected changes in the temperature patterns and increase in Adam's downtown area.

The high concentration of built-up surface generated many environmental issues. The Urban heat island effect (UHI) is one of these environmental issues in Adama City, where air temperatures in densely built-up areas are higher than in the surrounding rural areas. The root causes for the formation of heat islands in the town is due to the absorption of solar radiation by building structures, roads, and other hard surfaces. The absorbed heat is subsequently re-radiated to the surroundings and increases temperatures.

Therefore, air temperature rises, particularly in areas with high density. The real need for vegetation, greenery, and the low albedo of urban surfaces are quite important parameters regarding the heat island foundation effect in selected sites.

Raising awareness and integrating with different development about the issue of urban heat island mitigation measures is more important. Those strategies will not acquire without good level of understanding of the effect of the outdoor living environment on the indoor environment and put human comfort and health at risk. More effort and reinforcement are needed from decision-makers and urban planners to mitigate the UHI and reduce its effect on Adama City.

5.2 Recommendation

The main aim of this section is to define the requirement to decrease the urban heat island event and propose some solutions to mitigate UHI effects and have Adama City more livable and healthy. Based on the above problem analysis and findings, the following recommendation was set to mitigate urban heat islands in Adama City.

Adopting usage of Green Roof

- ✓ Greening Roof Benefit from slowing down urban heat islands, mainly in two aspects: The transpiration of plants can consume a large amount of heat from the environment, thereby reducing the temperature. And the plant's coverage for the surface of the building could reduce direct solar radiation.

- ✓ Cool rooftops through shading and evaporative cooling and provide additional insulation to improve building energy performance.

Promote planting Vegetation along the roadside and around buildings.

- ✓ We are planting greeneries along transportation corridors (roadsides and alongside lanes), which play a great role in decreasing noise and air pollution.
- ✓ Greening of parking lots is very important to create shade on paved surfaces. The shade from the trees will also protect the pavement from significant thermal variations and extend its lifespan. And also Location of cars under shading parking areas will help to decrease evaporative emissions that contribute to raising the level of urban ozone.

- ✓ Vegetation around buildings for optimal cooling, the vegetation planted around a building protects the building from solar radiation.

- ✓ Greening dwelling areas be promoted which have high value in lowering the amount of heat absorption and also improving air quality water quality through retention of rainwater in the ground and soil erosion control, and health benefits for the population, including protection from ultraviolet (UV) radiation.

Improving Pavement materials

- ✓ They are paving Pedestrian streets, parks, pedestrian walkways, bicycle paths, and parking lots through Impermeable interlocking paving stones, which allow rainwater to percolate through permeable joints.

- ✓ Increase surface moisture; evaporative cooling reduces runoff by promoting porous pavement.
- ✓ They are promoting and implementing colored and permeable paving material for pedestrian ways and streets in the town. By adding reflective pigments (colors) to asphalt and concrete, which increase their reflectivity.

Promoting Cool roofs for flat-roof buildings

- ✓ Use high-performance roof coatings products, such as elastomeric and polyuria membranes, light-colored tiles, and gravel, which all have higher albedos than conventional materials (for flat roofs only) in areas subject to the urban heat island effect, since when installed on a sloped roof, they create glare.

Placing Vegetation on Buildings

- ✓ The usage of plants in balconies or using different spaces of hot surfaces, like walls and roofs of buildings, with greenery for improving the urban thermal environment could have advantages to decrease the temperature and the influence of UHI.

Take into consideration building layout and orientation in the urban design process.

- ✓ Tall buildings should take into consideration that the sides of the buildings are subject to long hours of exposure to sunlight and wind direction.

- ✓ Measures such as the development of “wind paths” that use locally circulating winds for urban ventilation should be incorporated into land use planning systematically and comprehensively.

- ✓ New urban development design (urban geometry) should then be a compromise between environmental engineers, architects, and urban planners. These professionals must be educated about the importance of climatic factors for urban design and planning.

Promoting High albedo building materials and light surfaces

- ✓ Increasing the Albedo of Building Materials, it is advisable to use high Albedo tiles for the sides of the buildings. Materials with high albedo could decrease the heat of solar achieved by the surface temperature of the material on days.

- ✓ Promote materials with light colors for the facade of buildings. The technical department of Planning and Architecture of the municipality plays a key role play to consider and controlling the usage of high-albedo materials to decrease the effects of UHI.

Approaches from the Perspective of urban planning

- ✓ In cooperation with residents, organizations, and local governments, urban planners are strongly expected to play a leading role in facilitating mitigation measures and incorporating them into urban planning projects like structural plans, local development plans, and urban renewal from the beginning.
- ✓ Urban heat island mitigation measures must involve not only individual measures based on environmental technologies but a participatory approach promoted by involving different stakeholders.

Adopting Policy for Implementation

Priorities for implementing urban heat island mitigation measures must be set. Give priority to the application of urban heat island mitigation strategies in the areas where populations vulnerable to heat live.

Research Fund Acknowledgement

This research project is funded by Adama Science and Technology University under the grant number ASTU/SM-R/779/23, Adama, Ethiopia.

REFERENCES

Akbari, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, *70*(3), 295–310.

Akbari, H., Bretz, S., & Kurn, D. M. (1997). Peak power and cooling energy savings of high-albedo roofs. In *Energy and Buildings* (Vol. 25, Issue 2).

Akbari, H., Damon Matthews, H., & Seto, D. (2012). The long-term effect of increasing the albedo of urban areas. *Environmental Research Letters*, *7*(2).

Arabi, R., Shahidan, M., Kamal, M. S., Jaafar, M., & Rakhshandehroo, M. (2015). Mitigating Urban Heat Island Through Green Roofs. *Current World Environment*, *10*(Special-Issue1), 918–927. https://doi.org/10.12944/cwe.10.special-issue1.111

Balew, A., & Korme. (2020). Monitoring land surface temperature in Bahir Dar city and its surrounding using Landsat images. *Egyptian Journal of Remote Sensing and Space Science*, *23*(3), 371–386. https://doi.org/10.1016/j.ejrs.2020.02.001

de Almeida, C. R., Teodoro, A. C., & Gonçalves, A. (2021). Study of the urban heat island (Uhi) using remote sensing data/techniques: A systematic review. *Environments - MDPI*, *8*(10), 1–39. https://doi.org/10.3390/environments8100105

Dewan, A., Kiselev, G., Botje, D., Mahmud, G. I., Bhuian, M. H., & Hassan, Q. K. (2021). Surface urban heat island intensity in five major cities of Bangladesh: Patterns, drivers and trends. *Sustainable Cities and Society*, *71*(April), 102926.

Forest, Mcpherson, E. G., Simpson, J. R., & Peper, P. J. (2006). *T ree Guide Community*. *November*.

Gartland. (2009). Lisa Gartland. Heat Islands. Understanding and mitigating heat in urban areas. *Revista de Geografía Norte Grande*, *121*(43), 119–121.

Grant, R. H., Heisler, G. M., & Gao, W. (2002). Estimation of Pedestrian Level UV Exposure Under Trees¶. *Photochemistry and Photobiology*, *75*(4), 369.

Grundstein, A., & Dowd, J. (2011). Trends in extreme apparent temperatures over the United States, 1949-2010. *Journal of Applied Meteorology and Climatology*, *50*(8), 1650–1653.

Jalan, S. (2014). Spatio-temporal assessment of land use/ land cover dynamics and urban heat island of Jaipur city using satellite data. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *XL–8*(1), 767–772.

Jáuregui, E., & Luyando, E. (1999). Global radiation attenuation by air pollution and its effects on the thermal climate in Mexico City. *International Journal of Climatology*, *19*(6), 683–694.

Kifle, B. (2003). Urban Health Island and its feature in Addis Ababa (A case study). *Fifth International Conference on Urban Climate*.

Malik, R. (2016). *Green strategy*. 1–23.

Mallick, J. (2008). Estimation of land surface temperature over Delhi using Landsat-7 ETM+. *J. Ind. Geophys. Union*, *12*(3), 131–140.

Nowak, D. J. (2007). Urban and Community Forestry in the Northeast. *Urban and Community Forestry in the Northeast, January 2010*.

Oke, 1982. (n.d.). *The energetic basis of the urban heat island - Oke - 1982 - Quarterly Journal of the Royal Meteorological Society - Wiley Online Library*.

Oke, T. R. (1995). Wind Climate in Cities. *Wind Climate in Cities, December*.

Plan, The Trust for Public Land, 2015. (2008). *Section 5 Inventory of Lands of Conservation & Recreation Interest (Open Space Inventory)*.

Rajeshwari A... (2014). Estimation of Land Surface Temperature of Dindigul District Using Landsat 8 Data. *International Journal of Research in Engineering and Technology*, *03*(05), 122–126.

Republic, C. (1999). *15 th international congress of biometeorology & international conference on urban climatology " biometeorology and urban climatology at the turn of the millennium "*.

Robitu, M. (2006). Modeling the influence of vegetation and water pond on urban microclimate. In *Solar Energy* (Vol. 80, Issue 4, pp. 435–447).

Rousta, I., Sarif, M. O., Gupta, R. D., Olafsson, H., Ranagalage, M., Murayama, Y., Zhang, H., & Mushore, T. D. (2018). Spatiotemporal analysis of land use/land cover and its effects on surface urban heat Island using landsat data: A case study of Metropolitan City Tehran (1988-2018). *Sustainability (Switzerland)*, *10*(12).

Stewart, I. D. (2011). A systematic review and scientific critique of methodology in modern urban heat island literature. *International Journal of Climatology*, *31*(2), 200–217.

Stone, B. (2012). The city and the coming climate: Climate change in the places we live. In *The City and the Coming Climate: Climate Change in the Places we Live* (Vol. 9781107016, pp. 1–193).

Suszanowicz. (2019). The impact of green roofs on the parameters of the environment in urban areas-review. *Atmosphere*, *10*(12).

Thani, S. K. S. (2012). Modification of Urban Temperature in Hot-Humid Climate Through Landscape Design Approach: A Review. *Procedia - Social and Behavioral Sciences*, *68*, 439–450.

The City of Boston. (2014). *2014 Climate Action Plan Update*. 80.

Theeuwes, N. E., Steeneveld, G. J., Heusinkveld, R. J. R. B. G., & Holtslag, A. A. M. (2012). 197 : Mitigation of the urban heat island effect using vegetation and water bodies. *Energy*, 2011–2013.

USA Environmental Protection Agency. (2008). Reducing Urban Heat Islands: Green Roofs. *Heat Island Reduction Activities*, 1–23.

Voogt, J. A., & Oke, T. R. (1997). Complete urban surface temperatures. *Journal of Applied Meteorology*, *36*(9), 1117–1132.

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, *86*(3), 370–384.

Wang, C., & Zhou, X. (2019). Study on Climate Impacts on Asphalt Pavement in Tibet, China. *Journal of Geoscience and Environment Protection*, *07*(10), 49–59.

Warkaye, S., Suryabhagavan, K. V., & Belliethathan, S. (2018). *Urban Green Areas to Mitigate Urban Heat Island Effect : The Case of Addis Urban Green Areas to Mitigate Urban Heat*

Island Effect : The Case of Addis Ababa , Ethiopia. *October*.

Yamamoto, Y. (2005). Measures to Mitigate Urban Heat Islands. *Environmental and Energy Research Unit. Quaterly Review*, *18*, 65–83.

Zhang, Z., Paschalis, A., Mijic, A., Meili, N., Manoli, G., van Reeuwijk, M., & Fatichi, S. (2022). A mechanistic assessment of urban heat island intensities and drivers across climates. *Urban Climate*, *44*, 101215.

Zhong, X., Hu, M., Deetman, S., Steubing, B., Lin, H. X., Hernandez, G. A., Harpprecht, C., Zhang, C., Tukker, A., & Behrens, P. (2021). Global greenhouse gas emissions from residential and commercial building materials and mitigation strategies to 2060. *Nature Communications*, *12*(1), 1–10.

APPENDIX

Adama Science and technology university (ASTU)

School of Civil Engineering and Architecture

Department of Environmental Architecture (EA)

Appendix I

Data collection format at the Field

Traverse ------------------------------------

Points	Measuring time	Temp. record (^{o}C)	Location points		Land use/activity	Description
			Lat.	Long.		
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						

Appendix II

Adama Science and technology university (ASTU)

School of Civil Engineering and Architecture

Department of Environmental Architecture (EA)

Structured Questioners

Dear respondents, the purpose of these questionnaires is to support Research on **Mitigating downtown urban heat islands through urban design in the case of Adama City.**

Declaration: The information given will be treated with and used for academic purposes only. Please answer the questions as instructed.

Thank you for your priceless time

Questioner No………………...

Date………………………...

Respondents Details

1. **Name** (Optional)………………………………………………………………………

2. **Age:** 1. below 18 ☐ 2. 18-36 ☐ 3. 37-55 ☐ 4. 55-75 ☐ 5. Above 75 ☐

3. **Sex:** 1. Male ☐ 2. Female ☐

4. **Marital Status:** 1. Single ☐ 2. Married ☐ 3. Divorced ☐ 4. Separated ☐ 5) Others Specify……

5. **Educational Level:** 1. No formal education ☐ 2. Primary level ☐ 3. Secondary level, ☐ 4. Tertiary College ☐ 5. University level ☐

6. **Occupation:** 1. Formal employment ☐ 2. Self-employed ☐ 3. Pension ☐ 4. Daily laborer ☐ 5. Others ☐

7. For how long years have you lived in Adama city?

………………………………………………

8. Location of your living area /house/ in the town? 1) Downtown ☐ 2) dispersed residential neighborhood ☐ 3) Outskirt/ periphery ☐ 4) other ☐

9. from what is your house constructed? 1) Mud and wood ☐ 2) Concrete and HCB ☐ 3) Brick 4) ☐ Iron sheet ☐ 5) other ☐

10. from what do your offices construct? 1) Mud and wood 2) Concrete and HCB 3) Brick 4) Iron sheet 5) other

11. What Location of your office area in the town? 1) Downtown 2) dispersedly developed area 3) Outskirt/ periphery 4) other

12. Is there any temperature difference within the town?

....

13. In what season do the temperatures of the town increase?

....

14. Is there any temperature difference recently in the town? 1) Yes 2) No

15. What about the effect of temperature in your living area and /or workplace?...

16. At what time are the temperature effects more increased/ difficult? 1) in the day time 2) at nighttime

17. If there is a high temperature/ hot air condition/ what measures do you take to overcome it?..

18. Is there any problem faced you as a result of increased temperature? 1) Yes 2) No

19. If your above answer is "yes," justify it…………………………………………………

20. Is that comfortable to walk in the midday or harsh times in the downtown area?

1) Yes 2) No

21. If the above answer is "No," why?..

22. What do you suggest to the government or other stakeholders to overcome this problem in the town?...

Table 4:7 Summary of respondents

No	Response type	Frequency	%	Description
1	Responded to the issue	192	96.5	They agree with the issue and respond to the questions and give available data.
2	No response to the issue	7	3.5	Ignore the issue.

Appendix III

Adama Science and technology university (ASTU)

School of Civil Engineering and Architecture

Department of Environmental Architecture (EA)

Questionnaires for office interview

Dear respondents, the purpose of these questionnaires is to support Research on **Mitigating downtown urban heat islands through urban design in the case of Adama City.**

Declaration: The information given will be treated with confidentially and used for academic purposes only, so Please answer the Questions as instructed.

Office Name: Adama referral hospital

1. Name of official …………………………………………………………………........
2. Specialization by…………………………………………………………………………….
3. Work experience…………………………………………………………………………
4. What type of disease is caused by the effect of high temperature?
   ………………………………………………………………………………………………
5. Which age group the disease mostly affects? ....
6. How many people are affected by this type of disease each year?
   ....
7. How many people die each year of this type of disease? ....
8. What about its trend of effect on human health? 1) increasing 2) decreasing
9. If the above answer is “increasing” by what scale?
   ....
10. What type of measure must people take to decrease the effect?
    ....

Appendix IV

The purpose of this table is to know the albedo building materials standards and their amount of emissivity to support Research on Mitigating downtown urban heat islands through urban design in the case of Adama City.

Table: 4.10 Albedo material standards

Name	Surface	Emissivity	Albedo value
Ground	Asphalt	0.95	0.125
	Grass	0.93	0.2.5
Facades	Brick	0.91	0.3
	Concrete	0.805	0.225
	Wood	0.9	0.15
	Stone	0.9	0.275
	Corrugated iron	0.205	0.13
Roofs natural	Tar roofs	0.92	0.13
	Forests	0.97	0.15
	Water	0.97	

Table 4.13 Name of the albedo value.

No	Name	Albedo Value
1	Bare Soil	0.17
2	Fresh Asphalt	0.04
3	Green Grass	0.25
4	New Concert	0.55
5	Worn Asphalt	0.12
6	Trees	0.15-0.18
7	Corrugated roof	0.1 - 015
8	Colored paint	0.15 – 0.35

Appendix V

Built-up Expansion in the years 2013 and 2023.

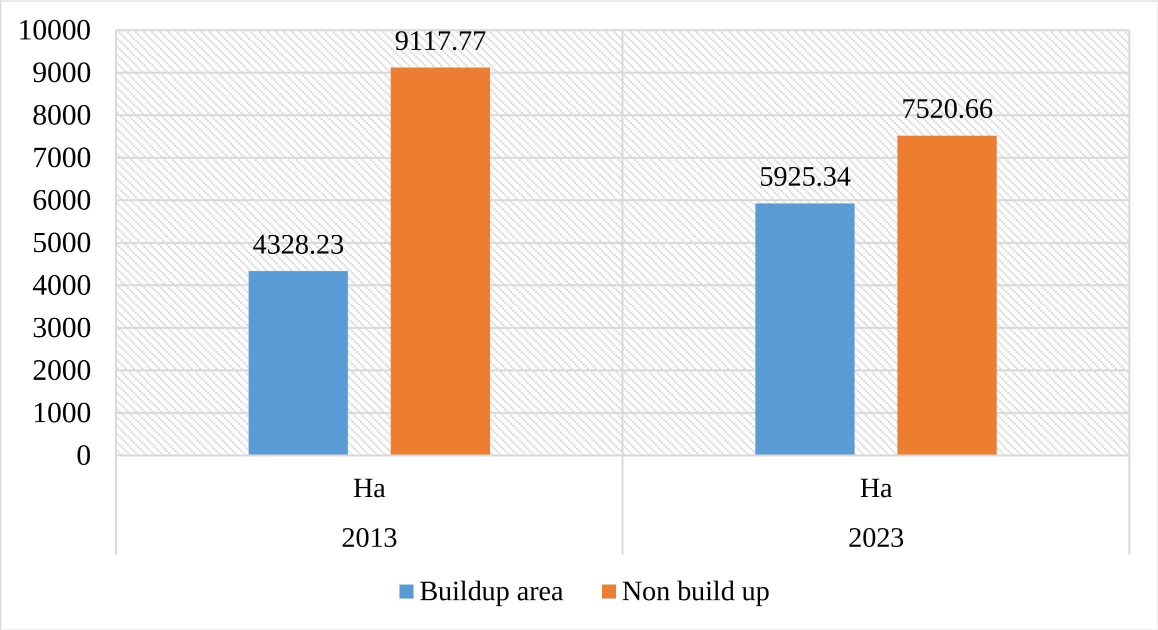


Figure 4.31 Buildup area extent between 2013 and 2023