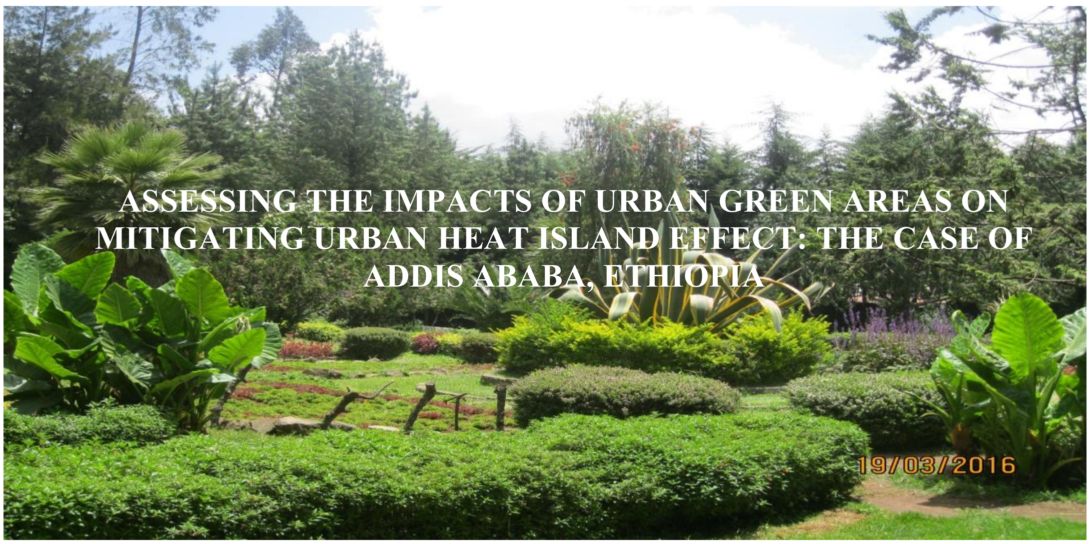
ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE
SCHOOL OF EARTH SCIENCE



ASSESSING THE IMPACTS OF URBAN GREEN AREAS ON MITIGATING URBAN HEAT ISLAND EFFECT: THE CASE OF ADDIS ABABA, ETHIOPIA

A Thesis Submitted to School of Graduate Studies Addis Ababa University for the Partial Fulfillment of the Requirements for the Degree of Masters of Science in Remote Sensing and Geo-Informatics

BY
Samson Warkaye Lamma

Advisor: Dr. K.V. Suryabhagavan
Co-Advisor: Dr. B. Satishkumar

June 2016
Addis Ababa

ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE
SCHOOL OF EARTH SCIENCE

ASSESSING THE IMPACTS OF URBAN GREEN AREAS ON MITIGATING URBAN HEAT ISLAND EFFECT: THE CASE OF ADDIS ABABA, ETHIOPIA

A Thesis Submitted to School of Graduate Studies Addis Ababa University, for the Partial Fulfillment of the Requirements for the Degree of Masters of Science in Remote Sensing and Geo-Informatics

BY
Samson Warkaye Lamma
(GSR/1670/07)

Advisor: Dr. K.V. Suryabhagavan

Co-Advisor: Dr. B. Satishkumar

June 2016

Addis Ababa

Acknowledgements

First and for most, I thank "Almighty God" for the strength and patience that he gave me to complete my study successfully. I also thank my beloved father Mr. Warkaye Lamma, for his continuous effort to complete my study.

I express my honest gratitude to my Advisor, Dr. K. V. Suryabhagavan, Associate Professor, School of Earth Sciences, Addis Ababa University, for his guidance and valuable suggestions during the research work. And also, I also thank my Co-Advisor Dr. B. Satishkumar, Assistant Professor, Environmental Science Program, Addis Ababa University, for his constant encouragement, helpful discussions and valuable comments.

I also greatly indebted to thank Mr. Sultan Mohammed, Director General of Ethiopian Mapping Agency, for his generosity to get this MSc program and Remote Sensing and GIS Directorate in delivering me the necessary data and my colleagues for their technical support. I am also very grateful to thank, the National Meteorological Agency, for their most appreciable support in delivering an instrument (Whirling Psychrometer) and meteorological data, which is a very important source of support for the study.

I thank Mss. Tigist Debebe for her motivational and psycho-social support that is important to build a confidence to succeed my study and for this endeavor for the care and support during my work. I also greatly thank Mr. Mesfin Hunduma for his great support for my study.

My deep gratitude goes to the School of Earth Science, and Remote Sensing and Geo-informatics department for their my classmates, who are always working with me, sharing ideas, skills and experience to become a full-fledged professional in the field of Remote Sensing and Geo-informatics. At last but not least, I thank those whose names could not be mentioned here, for their constant encouragement and cooperation.

Contents

List of Figures

List of Tables

Abbreviation

AACBPCDAA Addis Ababa City Beautification, Parks, Cemetery Development and Administration Agency

AR5 Fifth Assessment Report

CO2 Carbon Dioxide

CRGE Ethiopia's Climate Resilience Green Economy

CSA Central Statistical Agency

EEA European Environment Agency

EN English Nature

ETM+ Enhanced Thematic Mapper Plus

GIS Geographic Information System

GHG Green House Gas

GPS Global Positioning System

IPCC Intergovernmental Panel on Climate Change

LST Land Surface Temperature

LU/LC Land Use/Land Cover

MEF Ethiopia Ministry of Environment and Forestry

Mt CO2e Million metric tons of carbon dioxide equivalent

NASA National Aeronautics and Space Administration

NDBI Normalized Difference Built-Up Index

NDVI Normalized Difference Vegetation Index

OLI Operational Land Imagery

RS Remote Sensing

TIRS Thermal Infrared Sensor

TM Thematic Mapper

UHI Urban Heat Island

UN United Nation

US EPA United States Environmental Protection Agency

UTM Universal Transverse Mercator

Abstract

Several studies have been conducted on analyzing the land surface temperature since 1970's other than Ethiopia in detail. Urban Heat Island (UHI) is the variation in Land Surface Temperature (LST) between the urban realm and the surrounding rural areas. Urban areas are experiencing large population density, an increase surface temperature and expansion of built-up environment, which this intern affects the micro-climate of the city and develops UHI. With regard to surface temperature, different parameters and data's were used to understand the situation, to examine its effect and for determining a solution to overcome the consequences. Input data's such as Landsat TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and Landsat 8 OLI – TIRS (Operational Land Imagery – Thermal Infrared Sensor) images, after conducting radiometric and geometric corrections, were used to produce results for analysis. For generating LST of the study area, using Landsat Satellite data, Single and Split Window Algorithms were applied. Measurement techniques, NDVI (Normalized Difference Vegetation Index), LST (Land Surface Temperature), NDBI (Normalized Difference Built-up Index) and Land-use/Land-cover were produced to examine the UHI effect and the positive influence of green areas. The result in correlating the LST and NDVI indicates that, more than 76% of the variability of the LST is due to the distribution of NDVI throughout the study area. Therefore, NDVI as indicator to LST is acceptable, because, it results in strong correlation. The maximum LST in the four base years (1985, 1995, 2006 and 2015), with slight decrease in 1995, it shows a gradual increment in the measured LST and area coverage. In 1985, the area under 17°C surface temperature covers 0.95km^2, 17–21°C covers 22.94 km^2 and 61.6% of the area received temperature between 27–31°C. The result also shows, the higher the value of the NDBI is the higher the LST. A dramatic land-use/land-cover change exhibited from 1985 to 2015. In 1985 the built-up covers 25.7%, in 1995 about 40.8, in 2006 was 48.31 and in 2015 become 59.64%. On the other hand, vegetation cover is decreasing from 16.6% to 9.54% for the year 1985 and 2015, respectively. Measured temperature in the selected public parks and surroundings, indicates that, there is a maximum of 5°C temperature increment. Urban Public Parks plays a major role in mitigating the Urban Heat Island Effect. Therefore, a proper planning should be considered by government and stakeholders for administering and developing green areas and individuals keep the surrounding green.

***Key words**: NDVI, NDBI, LST, UHI, Land-use/Land-cover.*

CHAPTER I

INTRODUCTION

1.1. Background of the study

The temperature of the Earth's surface is the result of a balance between the amount of energy coming in from the sun and the amount of energy radiated out by the Earth. Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2015) stated in the Fifth Assessment Report (AR5), the Earth experienced a warmer atmospheric condition since the pre-industrial Period. The IPCC (2015) indicates that climate change is already affecting many communities and will affect the sustainable development of a country from economic growth to food security. Statistical reports by IPCC (2015) shows that average surface temperature rose by 0.89% from 1902 to 2012, and global average temperatures will rise by 0.3% to 0.7% from 2016 to 2035. This climate change is mainly caused and accelerated by the increment of greenhouse gases which is mostly driven by economic and population growth. Specifically, the surface temperature increases due to the concentration of the people in the urban area, the waste from these congested structures and built-up surfaces. When greenhouse gases such as carbon dioxide, methane and nitrous oxide increased in the atmosphere, the reflected energy retained in the atmosphere and this plays a great role to increase the land surface temperature (Rajeshwari and Mani, 2014). As reported in the Second National Communication of Ethiopia by Ministry of Environment and Forestry (MEF, 2015), Methane and Carbon dioxide are primary greenhouse gases that are emitted through human activities in Ethiopia and accounts for 52 and 26 percent respectively all greenhouse gas emissions. Ethiopia's total emission of a greenhouse gas (carbon dioxide) represents less than 0.3% of global emissions (MEF, 2015). Ethiopia's Climate Resilience Green Economy Initiative (CRGE) (2011) developed a green economy plan where one of the pillars is protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks.

United States Environmental Protection Authority (US EPA, 2008)[1] defines Green Spaces as land that are partly or completely covered with grass, trees, shrubs or other vegetation types, where the area is undeveloped and is accessible to the public. Plots of land that are categorized under this definition are parks, community gardens, school yards, cemeteries, public seating areas. Similarly, Addis Ababa City Beautification, Parks and Cemetery

[1] http://www3.epa.gov/region1/eco/uep/openspace.html

Development and Administration Agency (AACBPCDAA) defines urban green areas as plots of land located in urban areas characterized by green vegetation, grass, shrubs, with or without buildings that give services to public who visits those places. These green places in the city are categorized as parks, trees along road divides, trees along foot paths, public seating places, cemeteries, recreational centers and road squares with green vegetation, and green areas around churches.

Urban Heat Island (UHI) is the warming atmospheric condition of urban areas from the surrounding rural areas (Siti et al., 2013). Urban developments such as road construction, business and residential buildings, and so forth reduces urban vegetation cover (Siti et al., 2013) and instead adds heat absorbing surfaces such as roof tops, concrete structures, paving's or impervious surfaces. Hence, these urban structures affect heat absorptive and radiative properties, leads to Urban Heat Island Effect (Gudina Legesse, 2014). A discussion made by National Aeronautics and Space Administration (NASA) (2016) states that, Earth like all physical features, reacts to an increase in incoming energy by warming up, and the warmer the objects gets, the more energy its surface radiates.

Geographic information system and Remote Sensing technologies are used widely in identifying green spaces, analyzing land surface temperature, conducting Normalized Difference Vegetation Index (NDVI) for vegetation cover analysis, processing of meteorological data, and also used in generating valuable information for effective decision making process. One of the problem regarding parks in the study area is scarcity of spatial data, where some of the parks documents (blue print) is not accessible to retrieve a spatial data, some are accessible in online sources and some doesn't have a spatial data. For this study, GIS and Remote Sensing technologies were used in the processing of raw data for output generation and analysis purpose; and also used to produce spatial data in relation to parks.

The global standard for access to green areas or per-capita distribution of green areas, which is, ratio of green areas in square meter to total population is 7 square meter, as regional level Africa maintains this standard. Functional public parks in Addis Ababa cover 957,650 square meter area (AACBPCDA, 2015). Per-capita distribution of these public parks to individuals in Addis Ababa is about 0.3 square meters, which is insignificant to the global standard (Kumilachew Yeshitla, 2013).

A study conducted by Nina and Ameur (2014) suggests, a higher temperature in the cities highly influences human well-being and health. According to Kumilachew Yeshitila (2013), green areas will provide the public or benefits the societies and the environment by providing clear air, maintaining biodiversity, helping cities build cheaper and long lasting drainage system, and keeping down the heating during the dry seasons. Therefore, greenery in the city is a direct influence on urban air temperature. In the urban areas of the city a special emphasis have given in developing green areas such as public parks, cemetery, road squares greenery, trees along road side. Besides the great importance of natural green areas in general and urban green areas (public parks for this study) on environmental services, plays an important role in giving social and psychological services for the well-being of the urban dwellers (Chiesura, 2004).

In the context of this study, the impacts of public parks on mitigating Urban Heat Island Effect addressed through the investigation of Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Built Up Index (NDBI), Land use/Land cover change and integration of field temperature measurements within and outside the park for a measured distance for analyzing the park cooling effect of each sampled public parks. In addition to this, questionnaires were delivered to individuals in the park, at the time of temperature data collection. The questionnaires emphasis on individual's perception towards green areas, public parks, environmental attitudes.

Therefore, the research considers the application of Remote Sensing and Geographic Information System in identifying and analyzing the implications of urban Public Parks in reducing urban heat island effect in the case of Addis Ababa.

1.3. Problem statement

Urban areas are experiencing a warm temperature condition. Studies suggested that more than 50% of the world population resides in urban areas (Cheng et al., 2014). Numerous studies found that urbanization increases the surrounding air and surface temperature, which consequently intensify the urban heat island (UHI) effect (Cheng et al., 2014). High temperature in urban areas affects health, economy, and living condition of urban dwellers; and biodiversity of the city (Gudina Legesse et al., 2014). Urban heat island is caused by the expansion of the built up environment and structures that have an additive implication to increase atmospheric temperature.

Developments undertaken in the city directly affects the biodiversity of the city. Areas once covered by vegetation were degraded due to development activities such as real estate, condominium houses, road construction, industries, and so forth. With the impacts of climate change and additional effects of human activities, decreased amount of vegetation cover and this leads to the higher concentration of greenhouse gases such as carbon dioxide, methane and nitrous oxide in the atmosphere. By the very nature of these gases absorb emitted and reflected energy of the earth. On the other hand, this condition increases the degree of atmospheric temperature.

The larger the area under built up, related structures and diversified human activities tends to increase the greenhouse gases and resulted to higher surface temperature. This urban situation leads to affect the urban residents' health and quality of life (Melissa, 2010).

Urban based green areas (parks) have the capability to moderate the atmospheric temperature. Therefore, governments' local, regional or both should give much emphasis on keeping urban parks functional and develop a strategy to build new green public parks or give opportunities to investors to build green areas (Melissa, 2010).

Green area coverage in the city is less than the standard (Kumilachew Yeshitla, 2013). The existence of green areas is highly related to the existence of human being. Green areas have a socio-economic and environmental impact on the development of a city. Green areas have a positive impact on mitigating, harnessing, and moderating the cities micro-climate. Public parks in general have a great importance in overcoming climate changes, moderating a city micro-climate, conservation of cities biodiversity. But in the case of Addis Ababa, public parks were not studied well.

Therefore, this study will focus on applying Remote Sensing and GIS technologies to identify and map public parks; and model the urban heat island effect in the case of Addis Ababa, Ethiopia.

2. Research objectives

2.1. General objective

The main objective of the study was to identify and assess the impacts of urban public parks in reducing urban heat island effect in Addis Ababa based on Remote Sensing and GIS techniques.

2.2. Specific objective

The specific objective of this research is listed below:-

- Identify and map urban public parks to increase the accessibility of public parks spatial data.
- To identify the Urban Heat Island of Addis Ababa through analyzing the algorithms NDVI, NDBI, LST, and Land-use/Land-cover change.
- To examine the impacts of Urban Public Parks on mediating urban heat island effect and generate Park cooling statistical chart.

3. Significance of the study

The research will contribute to generate a spatial information regarding parks that are located in Addis Ababa. Application of Remote Sensing and GIS technologies in analyzing parks will give a clear and valuable information to government and non-government organizations, policy and decision makers, researchers and professionals about parks distribution in the city for further expansion activities, how parks help to cope climate change consequences in the city, how parks mediate the urban atmospheric temperature. Hence, Ethiopia is applying a green resilience economic plan to overcome the effects of climate change on diverse economic, social, security issues (CRGE, 2011), the research will have a special contribution on overcoming UHI effects through giving a scientific output.

4. Scope of the study

AACBPCDAA (2015) reports that urban green areas includes public parks, greenery alongside road and road divide, road squares, cemetery, trees in churches and non-religious institutions. There are 19 public parks found in the study area giving services to the public. Due to the available resource (financial and material), the study will emphasis on the 8 sampled parks (from 8 sub cities one park from each sub city) located in Addis Ababa covering 323,660 m^2 area (Table 3.10). The study emphasized on the application of Remote Sensing and GIS technologies on generating a valuable information regarding LST, NDVI, NDBI, Land-use/Land-cover and park cooling distance of the study area in analyzing the impacts of public parks on mitigating the Urban Heat Island effect.

5. Limitation of the study

- Scarcity of spatial data of the public parks in Addis Ababa.
- Routine process to get a permission for data collection in the parks
- Public parks expected to give a recreation service were changed to other services.

6. Thesis Organization

This thesis has six chapters. The first chapter contains introduction, statement of the problem, research objectives, scope and limitation of the study. The second chapter focuses on reviewing literatures on urban heat island and urban green area definitions and characteristics, urban public park benefits, indices for analyzing land surface temperature and urban heat island effect and mitigation mechanisms. The third chapter emphasizes on study area explanation and justification, resource required and methodology followed. The fourth chapter is about results and fifth chapter on discussion part. The six chapter deals with conclusion and recommendation based on results and discussion presented.

CHAPTER II

LITERATURE REVIEW

2.1. Urban green area definition and characteristics

According to James et al. (2009) the terms green space and open space are often used interchangeably. James et al. (2009) considered green spaces as land, whether publicly or privately owned and consists of predominantly unsealed, permeable, surfaces such as soil, grass, shrubs, trees and water.

Urban areas are characterized by mosaics of land, which are commercial buildings, residential areas, industrial buildings, and these interspersed with green areas (Stephen and Jari, 2004). This green area play a major role in moderating the urban surface and air temperature, protects and controls air pollution, creates a pleasant or mild air. Green areas constitute major environmental resources of the urban landscape (Mensah, 2014). Urban green areas can be characterized as trees, grasses, short rooted flowers and shrubs along road divides, squares, public siting areas, public parks, institutions, churches, cemeteries, along riverside.

Hence, urban green areas are said to be the lungs of the urban dwellers, they have to be preserved and managed properly. According to Mensah (2014), green areas in the continent Africa is deteriorating as an alarming rate.

2.2. Urban land use change

In the study conducted by Jianguo (2014), the term urban has no unified definition, rather different definitions emphasis on various aspects of urban systems. In general, urban areas share common features such as high population density, extensive impervious surfaces, abundant built up structures, modified ecosystem functions and services. James et al. (2009) suggested that urban areas are made up of the built environment and the external environment between buildings. Land use is a term used to explain the area covered by features that have a specific purpose or usage (Pellika, 2008). Land use change characterizes the change in land use dynamics through time. Urban land areas characterize the features that are part of the urban area. These could be built up areas, green vegetated areas, bare land, impervious surfaces or concretes and water body. Previous studies clearly demonstrated that the implications of rapid urban growth are decreased vegetated areas, and instead increased the surface temperature and modified the urban microclimate (Siti et al., 2013).

The rapid growth of urban areas engaged in the process of further urbanization, urban land-use/land-cover changes are always in dramatic flux, further changing terrestrial biological, physical and meteorological processes, leading to severe ecological and environmental problems (Effat, 2014). UHI intensity is related to land use/land cover changes, such as the composition of built up areas, water bodies, vegetation covers (Chen et al., 2006). Studies conducted in analyzing the relationship between land use/land cover changes and UHI results in designing a proper land use planning.

Half of the world's population lives in cities, a share that is likely to reach 70 percent in 2050. Urban areas, such as Cities are major contributors to greenhouse gas emissions. Cities consume as much as 80 percent of energy production worldwide and account for a roughly equal share of global greenhouse gas emissions (The World Bank, 2010). The emissions in the greenhouse gas is the anthropogenic effect of the urban areas, the infrastructural developments, decrease in vegetation cover, emissions from industries, waste disposal by urban dwellers, activities conducted by urban dwellers which is also increase with increasing population increase. Therefore, the urban land use change has a tremendous impact on increasing the urban surface temperature, instead leads to the variation between urban and rural temperature, called Urban Heat Island Effect.

The Ethiopia's Climate Resilient Green Economy (CRGE) strategy (CRGE, 2011) states that the main drivers of Green House Gas Emission (GHG) are solid waste, liquid waste and off-grid fossil fuel energy which are caused by the increase in urban population, increase in number of towns and cities. Urban population increase and expansion of towns and cities will increase the GHG, CO_2 in the atmosphere from 4.7 Mt CO_2e in 2010 to 10.2 Mt CO_2e in 2030 (CRGE, 2011).

2.3. Urban green area standards

The development of urban green areas (public and/or private) should directly relate to the international standards. The World Health Organization (WHO) global standard for access to green areas, per-capita distribution of green areas is 7 m^2 (Kumilachew Yeshitla, 2013). The per-capita distribution of green areas as stated by United Nation (UN) is 30 m^2 (Hassan-Ali and Hooman, 2012). According to the report by Addis Ababa City Beautification, Parks and Cemetery Development and Administration Agency (AACBPCDAA) (AACBPCDAA, 2015) functional public parks in Addis Ababa are 19 and constitutes 931, 086 m^2 area coverage. Therefore, the per-capita distribution of green area is less than 0.3 m^2. The Agency 2015/16 fiscal year plan indicates 237,192.16 m^2 area is under-development for public green parks and this increases to 0.35 m^2, this is still less than WHO stated standards. To meet the minimum requirement 7 m^2, 2700 hectares of land should be used for development of urban green areas. A study conducted in Tehran by Hassan-Ali and Hooman (2012) indicates that, Ministry of Housing and Urban Development set the standard, 12 m^2 per-capita, and working comprehensively. In the case of Addis Ababa, even if a responsible body is formed (AACBPCDAA), a standard (per-capita distribution) is not defined and only to build a public park.

2.4. Urban green area benefits

These days, urban areas face numerous, complex, and interrelated environmental problems that have impacts on the residents' health and quality of life including the urban heat island effect, air and water pollution, increased runoff (Melissa, 2010). Urban green areas have diverse benefits to the city dwellers and also visitors (Stephen and Jari, 2004). Numerous studies indicated that, urban green spaces have a role in improving the bio-physical qualities of the urban environment through providing cooling effect, reducing air and water pollution and noise and wind filtering, carbon sequestration, micro climate stabilization and alleviate heat island effect (Chiesura, 2004; Zhou et al., 2011; Xiaoyun et al., 2015). Besides environmental services, urban parks provide social and psychological services, which are of crucial significance for the livability of modern cities and the well-being of urban dwellers (Chiesura, 2004). Patrick and Richard (2013) discussed that, green spaces in urban areas can regulate urban climate.

2.5. Public parks in urban area

Public parks are green areas developed and administered by a government body, where their services are accessed to the societies. Addis Ababa City Beatification, Parks and Cemetery Development Administration Agency (AACBPCDAA) (AACBPCDAA, 2015) report indicates that there are 19 public parks giving services to the residents. An emphasis is also given to develop other parks in the city. But, how these parks are accessible to the beneficiaries were not given much attention. A study conducted by Olga et al. (2007) discussed the recommendation made by European Environment Agency (EEA), which suggests people should have access to green space within 15 minute walking distance. Similarly, a UK government agency called English Nature (EN), with much emphasis recommends that people living in towns and cities should have an access to natural green space less than 300 m from home (Olga et al., 2007). Public parks as well as private gardens play a critical role in supporting biodiversity and providing important ecosystem services in urban areas (Olga et al., 2007).

2.6. Land surface temperature and vegetation indices

Land Surface Temperature (LST) refers to the surface temperature which we directly sense it. When the LST rises, it causes unbalanced environmental situations like melting of ice, unpredicted rainfall, vegetation stress (Md Shahid, 2014).

LST of an area can be determined based on its brightness temperature and the land surface emissivity which is calculated through applying a Split Window Algorithm (Rajeshwari and Mani, 2014; Md Shahid, 2014).

The basis for using vegetation indices such as NDVI in studying LST is, the amount of vegetation presents is an important factor for analyzing LST (Weng et al., 2004). Studies conducted with regard to LST and NDVI relationship showed that, there is a strong positive correlation in between them (Rajeshwari and Mani, 2014).

2.7. Urban land surface temperature characteristics

Temperature of every surface depends on its surface energy balance; which is governed by its properties such as orientation and openness to Sun, sky and wind, radiative ability to reflect solar and infrared, and to emit infrared availability of surface moisture to evaporate, ability to conduct and diffuse heat, and roughness of the surface structure (Voogt, 2000). These properties of surface can determine the urban land surface temperature and also the mitigation mechanism which can be derived from those properties.

2.8. Urban Heat Island Effect

Urban Heat Island (UHI) is defined as a phenomenon that occurs when air and surface temperatures in urban areas significantly exceed those experienced in nearby rural areas (Oded et al., 2006; Tony, 2012; Sobrino et al., 2012). UHI is can also be defined as the difference between the air temperature within the city and the air temperature of its surroundings (Sobrino et al., 2012). Urban Heat Island can simply explain as the relative warmth of air temperature near the ground (Voogt, 2000). A research conducted by Meng and Liu (2013) discussed the UHI effect as a phenomenon of higher atmospheric and surface temperatures occurring in urban areas than in the surrounding rural areas as a result of urbanization ,and manifested by higher surface and air temperatures within urban environments compared to surrounding rural areas. According to Siti et al. (2013), one of the possible causes for UHI is a drastic reduction of the greener areas to built-up surfaces. When the natural land cover, especially the vegetated area was converted to build surfaces, traps incoming solar radiation during the day and then re-radiate it at night, increases the land surface temperature, and also characterizes the UHI effect (Walsh et al., 2011; Siti et al., 2013). Walsh et al., (2011) discussed that, anthropogenic sources such as central heating systems, air conditioning, transport and industrial processes emit heat directly into the urban area, buildings and infrastructures instead increases surface roughness that can reduce wind speeds, convective heat loss and evapotranspiration. Further, Walsh et al., (2011) noted that these anthropogenic factors contribute to increase atmospheric temperature. Patrick and Richard (2013) stated the urban heat island effect phenomenon as the significant change of the built environment in the cities, which are, solar radiation, air temperature, wind speed and relative humidity. Urban heat island effect is caused by the large areas of heat absorbing surfaces, reduction of vegetation and in combination with high energy use in cities (US.EPA. 2008). Urban heat island effect can increase urban temperatures by 5ºC (Patrick and Richard, 2013).

The UHI effect is directly related to the modification of land surfaces, with decreasing green and open areas and increasing areas of built-up surfaces. Especially dark colored buildings and impermeable surfaces (roads, Parking lots, building roofs and walls, industrial and commercial areas) are responsible for absorption of solar radiation (Escobedo and Dubbeling, 2014). In conjunction with the heat produced by transport, cooling systems and industrial activities, this contributes to a rise in ambient temperature in cities (Escobedo and Dubbeling, 2014).

2.9. Interactions between urban public parks and urban heat island effect

Many urban and suburban areas experience elevated temperatures compared to their outlying rural surroundings; this difference in temperature is what constitutes an urban heat island. The annual mean air temperature of a city with one million or more people can be 1 –3°C warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 12°C. Even smaller cities and towns will produce heat islands, though the effect often decreases as city size decreases (US EPA, 2008; URL[2]).

2.10. Urban heat island effect mitigations

Shade trees and smaller plants such as shrubs, vines, grasses, and ground cover, help cool the urban environment. According to US EPA reports (US EPA, 2008; URL[3]), strategies were designed to mitigate the Urban Heat Island Effect, through actively participating the community from the planning to the implementation stage and afterwards. One of the

URL[2] https://www.epa.gov/sites/production/files/2014-06/documents/basics compendium.pdf
URL[3] . https://www.epa.gov/heat-islands/heat-island-compendium

methods to mitigate the UHI (US EPA 2008,) was planting trees and vegetating the urban area. Trees and vegetation (shrubs, grasses, green covers, and vines) help to cool the urban environment through shading and evapotranspiration. Leaves and branches reduce the amount of solar radiation that reaches the area below the canopy of a tree or plant. The amount of sunlight transmitted through the canopy varies based on plant species. In the Summer time, generally 10 to 30 percent of the sun's energy reaches the area below a tree, with the remainder being absorbed by leaves and used for pho-tosynthesis, and some being reflected back into the atmosphere (US EPA, 2008).

CHAPTER III

MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

Ethiopia is one of a sub-Saharan country that retains a registered and accepted fastest economic growth in Africa and also in the world. Addis Ababa is the capital city of Ethiopia and also noted as the diplomatic hub of Africa. Addis Ababa's area coverage accounts for 526.47 $km^{2.}$ Absolute location of the city is 38°39′03″ –38°54′19″ E and 8°50′10″ – 9 ° 06′01″ N. Geographic locations and shape of the study area was shown on figure 1.

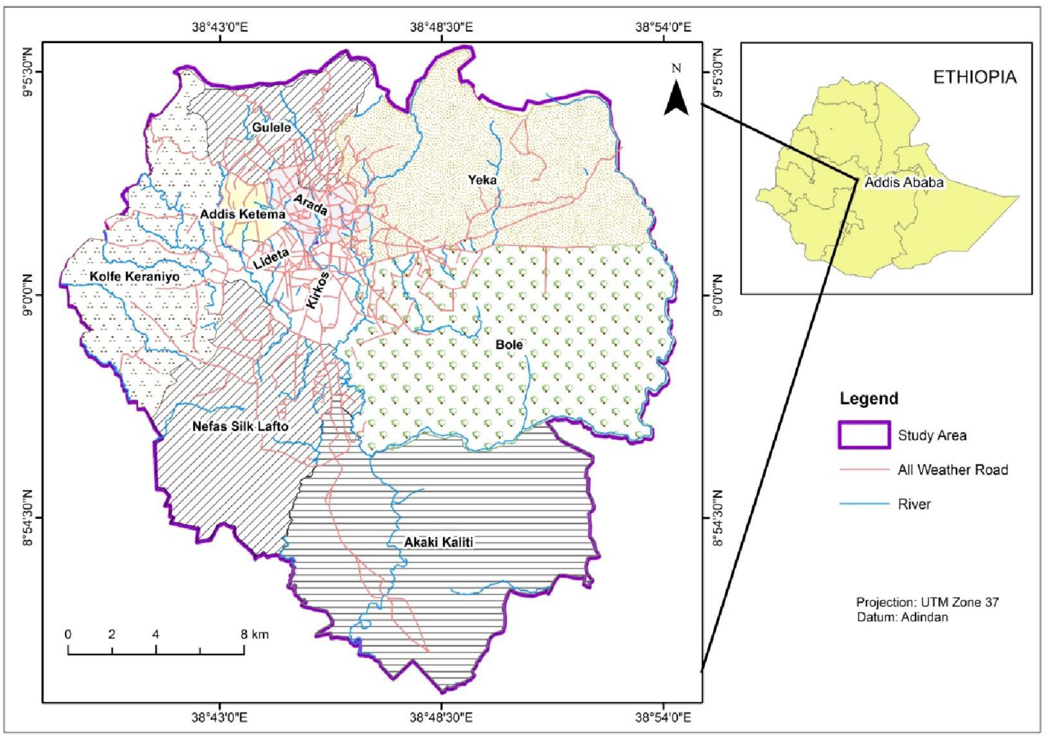


Figure 1. Location map of study area.

3.1.2. Topography

Addis Ababa is bounded by Entoto Mountain to the North, Yerer Mountain to the East, and Wechecha Mountain to the North West. The city elevation ranges from 2,015 m to 3,140 m above sea level. The lowest and the highest place with elevation 2,015 meter and 3140 meter above sea level respectively are located around Kality and Entoto Mountain. The topography of the study area can be visible from the figure 2.

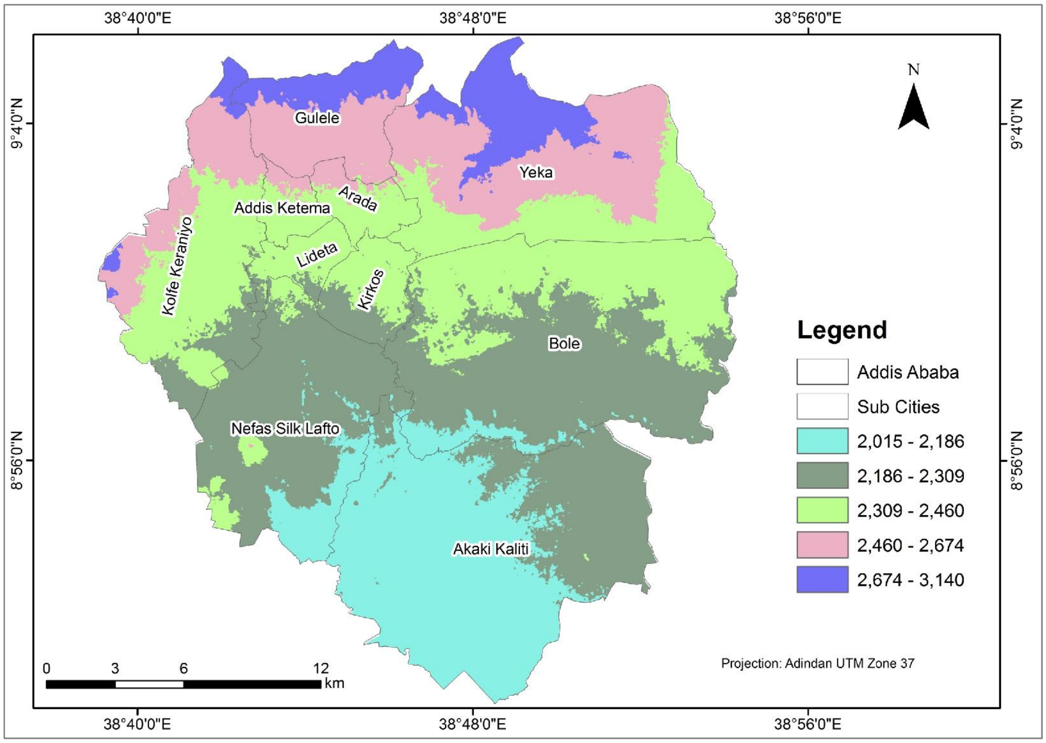


Figure 2. Elevation Map of the study area.

Slope of Addis Ababa indicates much the area with slope greater 21 degree is located in the northern part of Addis Ababa, which is characterized by Entoto Mountain. Slope variations can be seen in the figure 3.

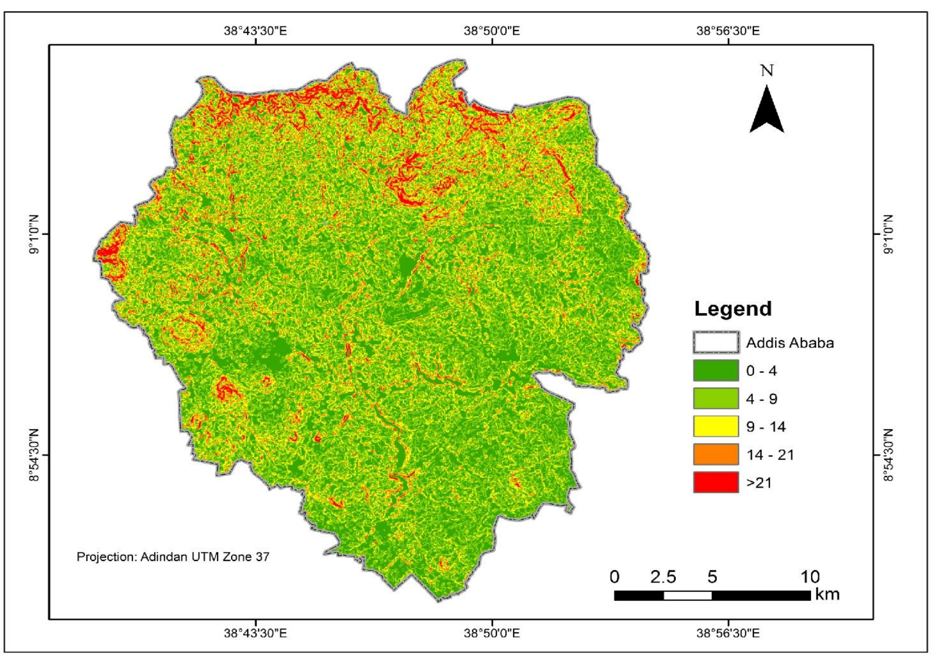


Figure 3. Slope map of the study area.

3.1.3. Demography

As per 2015/16 G.C population projection urban population of Addis Ababa is estimated as 3.352 million (CSA, 2015) (Fig. 4). The population of Addis Ababa in 2007 was 2,739,551 and within 8 years' time increased by 81.73 % and in 2015 reached to 3,352,000.

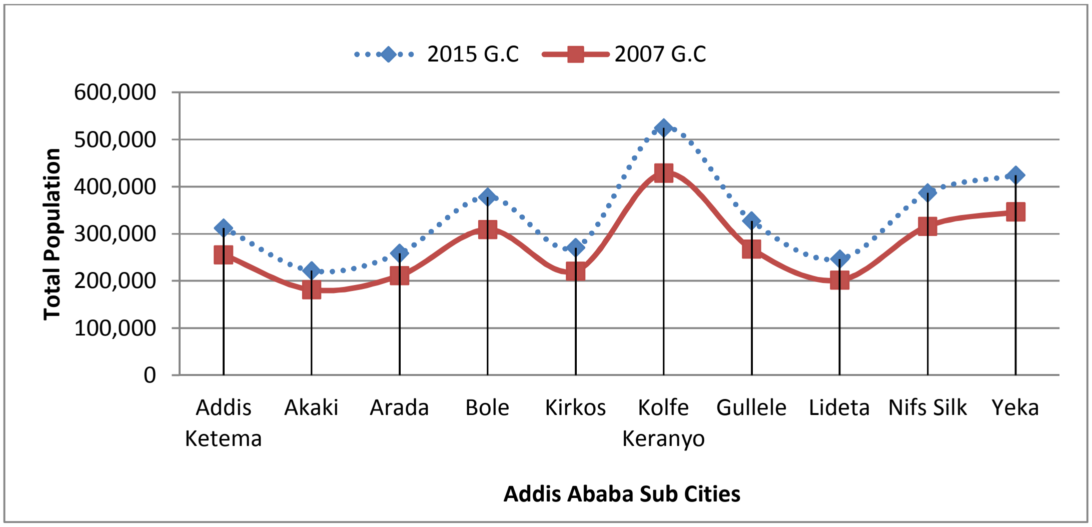


Figure 4. Demographic characteristics of study area.

3.1.4. Climate characteristics

Addis Ababa is said to be a Subtropical highland climate city (URL[4]). Addis Ababa has a pronounced rainfall peak during the summer (July to August) and exhibits a rainfall minimum during the winter (December to February). Average monthly temperature varies between 10^oC10°C and 20^oC20°C . Temperature (Fig. 5) and Rainfall (Fig. 6) recorded in the City of Addis Ababa for 30 years period from 1981 – 2010 (URL[5]) and this indicates that the average daily high temperature exhibited on the month of May is 18^oC, relatively low average daily temperature recorded during the month of November and December, 15^oC each.

URL[4] www.addisababacity.gov.et/index.php/en/city-hall/city-profile?format=pdf
URL[5] http://worldweather.wmo.int/en/city.html?cityId=162

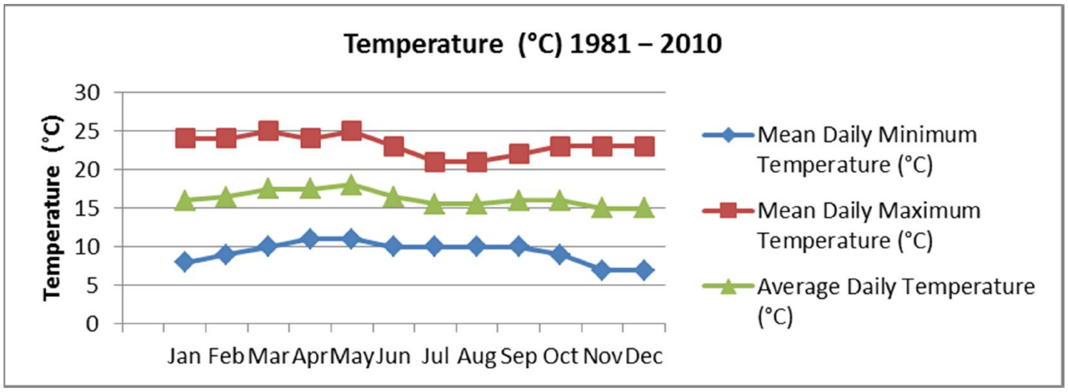


Figure 5. Mean average daily temperature (^{o}C) distribution 1981-2010.

Since, rainfall is one element of climate variability; the thirty year recorded amount of rainfall (Fig. 6) indicates the yearly distribution of rainfall in the study area. August month is the highest amount of rainfall, 290 mm, recorded. The minimum average amount of rainfall recorded during the month of November is 7mm and the same is for December.

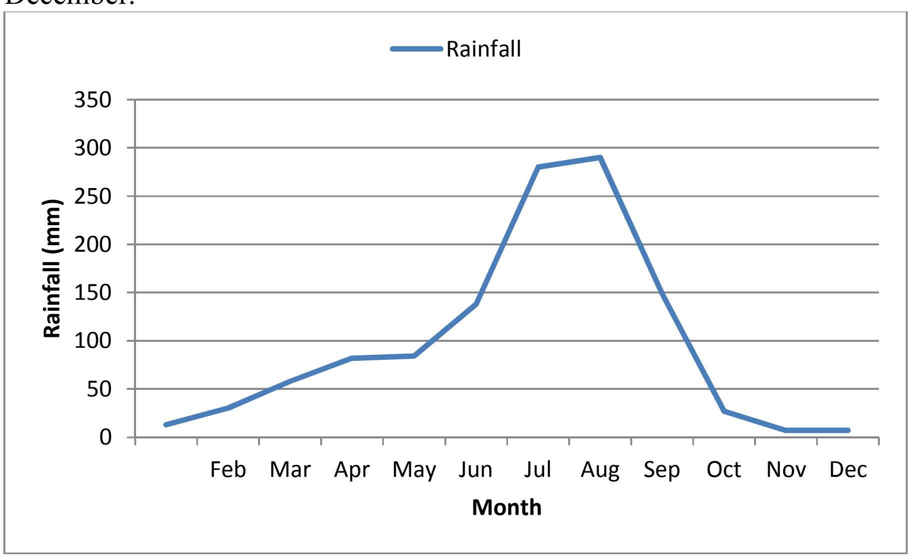


Figure 6. Mean total rainfall (mm) distribution 1981-2010.

3.1.5. Urban characteristics

Addis Ababa is a city undertaking a vast development program including settlement (condominium and real state houses), road, commercial buildings, government public service buildings, re-developing slum areas and other investment activities. When population increases, the use of utilities, infrastructural developments, pavements, and impervious surfaces, concrete also increases. These changes incorporated together have a great impact on increasing surface temperature.

3.1.6. Urban Public Parks

Addis Ababa City Beautification, Parks and Cemetery Development and Administration (AACBPCDA) (AACBPCDA, 2015) 2015/16 fiscal year plan suggested that 19 parks in Addis Ababa, which covers 931,086 m^2 of area are functional giving services to the public, and 9 parks with total of 237,192m^2 area planned to be developed in the future. For this specific study, 10 public parks in total and one public park for each sub city were randomly selected for the study as a sample site for collecting temperature data. However, 8 parks were covered for the sample collection, and two parks, Millennium Park in Akaki kality sub city currently is not giving the required service as a public park rather the buildings in the park were devoted to civil registration purpose. The second park, Peacock, it was not covered during the data collection period due to the routine process to get the permission. Fig. 7 depicts, the 19 public parks found in the study area and the 8 selected public parks for the study.

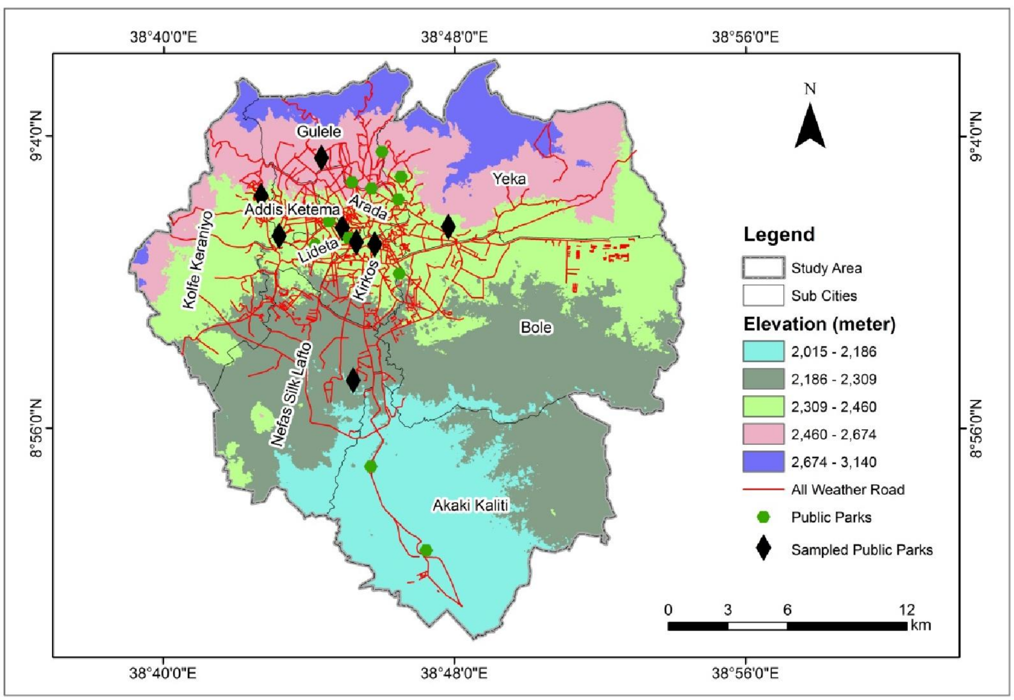


Figure 7. Public park distribution Map.

3.2. Data Acquisition

Landsat satellite data's are a continuous land remote sensing data used for analyzing land use changes, resource monitoring, disaster risk management, environmental monitoring are some important application areas out of multi-faceted use. In order to undertake the research study, Landsat TM (for the year 1985 and1995), Landsat ETM+ for 2006 and

Landsat 8 image for the year 2015 cloud free image the study area with path 168 and row 54 were acquired from institutions that deliver data free of charge, from United States Geological Service (USGS) (URL[6], URL[7], URL[8]]. The acquired data's with WGS84 projection system were projected to Universal Traverse Mercator (UTM) projection and Adindan datum, which is specific datum system to Ethiopia.

Landsat Thematic Mapper (TM)

Landsat 5 (TM) launched in 1984 and orbited the Earth until 2013 delivering a record of images of the Earth [URL[9]] for various applications. TM is a sensor mounted on the Landsat satellite to record the reflectance of the Earth surface with 7 bands (6 reflective bands and 1 thermal band). Table 1. Shows the wavelength of each band with their spatial resolution.

Table 1. Landsat 5 band description.

Bands	**Type**	**Wave length (micrometer-µm)**	**Spatial Resolution (meter)**	**Repeating Time**
Band 1	Visible	0.452 – 0.518	30	16 days
Band 2	Visible	0.528 – 0.609	30	
Band 3	Visible	0.626 – 0.693	30	
Band 4	NIR	0.776 – 0.904	30	
Band 5	NIR	1.567 – 1.784	30	
Band 6	Thermal	10.45 – 12.42	120	
Band 7	MIR	2.097 – 2.349	30	

NIR= Near Infrared, **MIR**= Mid Infrared

Landsat 7 (Enhanced Thematic Mapper plus – ETM$^+$)

Landsat 7 satellite equipped with ETM$^+$ sensor launched in April 1999**.** The sensor increases the capabilities of TM sensor adding a panchromatic band with 15 meter spatial resolution, no panchromatic band in TM sensor and a thermal infrared band with 60 meter resolution, where 120 meter spatial resolution in TM sensor. Table 2 Indicates the ETM+ sensor bands with their wavelength and spatial resolution descriptions. [URL[10]**].**

URL[6] http://earthexplorer.org
URL[7] ftp:ftp.glcf.umd.edu/glcf/Landsat/WRS2/p168/r054
URL[8] http://landsatlook.usgs.gov
URL[9] http://landsat.usgs.gov/about_mission_history.php
URL[10] http://geo.arc.nasa.gov/sge/landsat/l7.html

Table 2. Landsat 7 band description.

Bands	**Type**	**Wave length (micrometer-µm)**	**Spatial Resolution (meter)**	**Repeating Time**
Band 1	Blue	0.452 – 0.514	30	16 Days
Band 2	Green	0.519 – 0.601	30	
Band 3	Red	0.631 – 0.692	30	
Band 4	NIR	0.772 – 0.898	30	
Band 5	NIR	1.547 – 1.748	30	
Band 6	Thermal	10.31 – 12.36	60	
Band 7	MIR	2.065 – 2.346	30	
Band 8	Panchromatic	0.515 – 0.896	15	

NIR= Near Infrared, **MIR**= Mid Infrared

Landsat 8 Data

Landsat 8 satellite was launched in February 2013. The satellite carries two bush broom instruments: the Operational Land Imager (OLI) consisted of 9 spectral bands (band 1 – 9) and Thermal Infrared Sensor (TIRS) with two bands (band 10 and 11). The spectral bands of the OLI sensor provide an enhancement from the previous Landsat instruments, Landsat 5 and 7, due to the addition of two bands (band 1 and band 9). These additional elements, the wavelength and spatial resolution of Landsat 8 is indicated in Table 3 (Zhou et al., 2014).

Table 3. Landsat 8 band descriptions.

Bands	Type	Wave length (micrometer- µm)	Spatial Resolution (meter)	Repeating Time
Band 1	Coastal Aerosols	0.43 – 0.45	30	16 Days
Band 2	Blue	0.45 – 0.51	30	
Band 3	Green	0.53 – 0.59	30	
Band 4	Red	0.64 – 0.67	30	
Band 5	NIR	0.85 – 0.88	30	
Band 6	SWIR 1	1.57 – 1.65	30	
Band 7	SWIR 2	2.11 – 2.29	30	
Band 8	Panchromatic	0.50 – 0.68	15	
Band 9	Cirrus	1.36 – 1.38	30	
Band 10	TIR (TIRS 1)	10.60 – 11.19	100	
Band 11	TIR (TIRS 2)	11.50 – 12.51	100	

NIR= Near Infrared, SWIR= Short Wave Infrared, TIR= Thermal Infrared

Multi-temporal data's are used to analyze the changes in Normalized Difference Vegetation Index, land surface temperature and the built-up environment. From Landsat 5 and 7 for land surface temperature analysis the Thermal band (band 6), for NDVI analysis NIR (band 4) and Red (band 3) were used. Since Landsat 8 image has 11 bands, for land use land cover mapping all bands except band 1, 9, 10 and 11 were applied, for Normalized Difference Vegetation Index processing NIR (band 5) and Red (band 4) bands are used, for Land Surface Temperature analysis TIRS (Thermal Infrared Sensor) Band 10 and 11 and thermal constants K1 and K2 (Table 6) and other image numerical information's were retrieved from metadata of the image file.

With regard to land-use and land-cover map validation purpose online data source (Google Earth), land-use land-cover map for the year 2013/14 of Addis Ababa from Ethiopian Mapping Agency and ground Global Positioning System (GPS) data were used for validating the land use land cover classes.

Furthermore, SRTM and ASTER 30 meter resolution data were acquired from [URL[11]] and [URL[12]] respectively for Digital Elevation Model generation; data related to public parks area coverage and GPS locations collected from Addis Ababa City Beautification,

URL[11] http://earthexplorer.org
URL[12] http://gdem.ersdac.jspacesystems.or.jp/title_list.jsp

Parks and Cemetery Development Administration Agency and from field; Meteorological data (Minimum and Maximum temperature, wind speed) and temperature measuring instrument, Whirling Psychrometer were received from National Meteorological Agency of Ethiopia and additional meteorological data from the [URL[13]].

Software package

For pre-processing of Landsat image and SRTM data, ERDAS Imagine 2014 and ArcGIS 10.3; for data preparation for further analysis Global Mapper 10.1, SPSS, ERDAS Imagine 2014 and ArcGIS 10.3 and QGIS Desktop 2.8.1 software's were used.

3.3. Data processing and analysis method

3.3.1. Data processing

The acquired Satellite and ESRI format data were adjusted to Adindan UTM Zone 37 projection system. Therefore, the Landsat and SRTM image, topographic map, vector data of Addis Ababa were projected to Adindan UTM Zone 37.

Before any further processing of the downloaded Landsat images, a pre-processing technic was applied, which is radiometric correction. Radiometric correction is a removal of sensor or atmospheric 'noise' to more accurately represents the ground conditions. Radiometric corrections also modify DN values which are the account of 'noise', contributed by the effect of the intervening atmosphere.

Landsat ETM+ has a stripe because of Scan Line Corrector (SLC) error. These errors were corrected with the Focal Analysis in ERDAS Imagine 2014.

3.3.2 Radiometric calibration procedures

Image processing procedures that are used to correct errors, sensor or atmospheric and converting the DN values to radiance and then to reflectance are categorized as radiometric calibration (Chander et al., 2009; Parente, 2013). The tables (Table 4 – 7) indicates, the sensor calibration constants and DN values for the execution of correcting errors to get a new corrected value.

URL[13] http://apps.ecmwf.int/datasets/data/interim-full-daily

Table 4.TM spectral range, post-calibration dynamic ranges and mean exoatmospheric solar irradiance (ESUNλ) (Chander et al., 2009)

TM sensors (Q_{calmin} =1 and Q_{calmax} =255)							
Band Units	Spectral range (µm)	Center Wavelength	$LMIN_{\lambda}$ (W/m^2*sr* m)	$LMAX_{\lambda}$	Grescale (W/m^2*sr* m)/DN	Brescale (W/m^2*sr* m)	ESUNλ (W/m^2*m)
1	0.452 – 0.518	0.485	-1.52	169	0.671339	-2.19	1983
2	0.528 – 0.609	0.569	-2.84	333	1.322205	-4.16	1796
3	0.626 – 0.693	0.660	-1.17	264	1.043976	-2.21	1536
4	0.776 – 0.904	0.840	-1.51	221	0.876024	-2.39	1031
5	1.567 – 1.784	1.676	-0.37	30.2	0.120354	-0.49	220.0
6	10.45 – 12.42	11.435	1.2378	15.3032	0.055376	1.18	N/A
7	2.097 – 2.349	2.223	-0.15	16.5	0.065551	-0.22	83.44

Table 5. ETM+ spectral range, post-calibration dynamic ranges and mean exoatmospheric solar irradiance (ESUNλ)(Chander et al., 2009)

TM sensors (Q_{calmin} =1 and Q_{calmax} =255)											
Band Units	Spectral range (µm)	Center Wavelength	$LMIN_{\lambda}$ (W/m^2*sr* m)		$LMAX_{\lambda}$		Grescale (W/m^2*sr* m)/DN		Brescale (W/m^2*sr* m)		ESUN λ (W/m^2*m)
			Low Gain	High Gain	Low Gain	High Gain	Low Gain	High Gain	Low Gain	HighGain	
1	0.452 – 0.514	0.483	-6.2	-6.2	293.7	191.6	1.180709	0.778740	-7.38	-6.98	1997
2	0.519 – 0.601	0.560	-6.4	-6.4	300.9	196.5	1.209843	0.798819	-7.61	-7.20	1812
3	0.631 – 0.692	0.662	-5.0	-5.0	234.4	152.9	0.942520	0.621654	-5.94	-5.62	1533
4	0.772 – 0.898	0.835	-5.1	-5.1	241.1	157.4	0.969291	0.639764	-6.07	-5.74	1039
5	1.547 – 1.748	1.648	-1.0	-1.0	47.57	31.06	0.191220	0.126220	-1.19	-1.13	230.8
6	10.31 – 12.36	11.335	0.0	3.2	17.04	12.65	0.067087	0.037205	-0.07	3.16	N/A
8	2.065 – 2.346	2.206	-0.35	-0.35	16.54	10.80	0.066496	0.043898	-0.42	-0.39	84.90
PAN	0.515 – 0.896	0.706	-4.7	-4.7	243.1	158.3	0.975591	0.641732	-5.68	-5.34	1362

DN to Radiance conversion: for Landsat 5 and 7

$L\lambda = (Gain * DN) + Bias\lambda$ Eq(1)

Where;

$L\lambda$: is the calculated radiance associated to the ground area enclosed in the pixel and referred to the λ wave-length range of the specific band

$Gain\ and\ Bias\lambda$: are sensor specific calibration parameters defined before the launch

DN: is the digital number of pixel of the Landsat image.

Or radiance can be calculated as:

$L\lambda = \left(\frac{LMAX\lambda - LMIN\lambda}{QCALMAX - QCALMIN}\right) * (QCAL - QCALMIN) + LMIN$ Eq(2)

Where;

$L\lambda$: is the calculated radiance associated to the ground area enclosed in the pixel and referred to the λ wave-length range of the specific band

$QCAL$: Quantized calibrated pixel (Band value)

$LMAX\lambda$: is the spectral radiance that is scaled to $QCALMAX$

$LMIN\lambda$: is the spectral radiance that is scaled to $QCALMIN$

$QCALMIN$: is the minimum quantized calibrated value (corresponding to$LMIN\lambda$) in DN

$QCALMAX$: is the maximum quantized calibrated value (corresponding to$LMAX\lambda$) in DN

Radiance to Reflectance conversion: for Landsat 5 and 7

The output (radiance value) also calibrated to reflectance value. The algorithm used to obtain the reflectance value is:

$P\lambda = (\pi * L\lambda * d^2)/(ESUN\lambda * Cos\theta s)$ Eq(3)

Where;

$L\lambda$: is the spectral radiance at aperture calculated for each band

d: is distance from the Earth to the sun in Astronomical Units

$ESUN\lambda$: is the mean solar Exo-atmospheric irradiance

θs: is refers to solar zenith angle (90^o- sun elevation angle), to change this value to radian multiply the value by ($\frac{\pi}{180}$), π is equal to 3.14159.

The downloaded images are in TIFF (Tagged Image File Formats) were exported to imagine (.img) format for a simplified data processing. For land use land cover analysis:

from Landsat 5 band 1 to 5 and band 7 were layer stacked; from Landsat 7 band 1 to 5, band 7 were layer stacked and merged with panchromatic band 8 to get a 15 meter spatial resolution; from Landsat 8 band 2 to 7 were layer stacked and merged with panchromatic band 8 to get a multi-spectral 15 meter resolution image.

With regard to Digital Elevation Model (DEM), SRTM data with 30 meter resolution was downloaded from [URL[14]] and projected to UTM Zone 37 and Adindan Datum. Furthermore, the projected data is processed to get DEM and slope data using ArcGIS 10.3 software.

3.3.3. Results and Data Analysis

3.3.3.1. Normalized Difference Vegetation Index (NDVI)

The principle behind the Normalized Difference Vegetation Index (NDVI) is that 'green' leaves absorb radiation at Red wavelengths due to the presence of chlorophyll pigments whilst scattering radiance at very Near Infrared wavelengths due to the internal structure of the leaf (Farooq, 2012). NDVI is expressed as a standardized algorithm used to characterize the vegetation cover of an area above the ground using the reflected Red and Infrared band of Landsat Images. NDVI is a remote sensing method that is useful to analyze whether the area is characterized by live vegetation cover or not [URL[15]; URL[16]].

For Landsat 5 data the NDVI formula is: Zha et al., 2010; Saad and Nitin, 2014) $(Zha\ et\ al., 2010;\ Saad\ \&\ Nitin, 2014)$

$$NDVI = \frac{NIR-Red}{NIR+Red} \qquad \text{Eq(4)}$$

Where, NIR (Near Infrared band 4 from 0.76 – 0.90 µm) and Red band (Band 3 from 0.63 – 0.69 µm)

For Landsat 7 data the formula used for calculating NDVI is: (Weng et al., 2004)

$$NDVI = \frac{NIR-Red}{NIR+Red} \qquad \text{Eq(5)}$$

For Landsat 8 data the standard algorithm for NDVI is: (Varshney, 2013; Rajeshwari and Mani, 2014).

URL[14] http://earthexplorer.org
URL[15]www.nasa.gov/topics/earth/features/onscure_data.html
URL[16] http://earthonservation.nasa.gov/features/MeasuringVegetation

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad \text{Eq(6)}$$

Where, NIR (Near Infrared band5 from 0.85-0.88µm) and Red band (band 4 from 0.64-0.67 µm). The resultant value is a ratio ranging from -1 to 1. The value close to 0 represents no or little vegetation and close to 1 represents the highest density of vegetation cover [URL[4]]. Applying NDVI algorithm leads to compare the presence of vegetation cover with that of the parks.

3.3.3.2. Normalized Difference Built-up Index (NDBI)

Remote Sensing time serious data's will help us to illustrate the urban development overtime through mapping the built-up changes (Varshney, 2013). The built-up land information can be extracted using the algorithm NDBI and the value 1 indicates the positive value for the built-up areas (Varshney, 2013); Zhou et al., 2014). The algorithm is an automated means to extract the built-up region. The NDBI is often mixed with plant noise. Therefore, NDVI is used to filter out the noise.

The formula used (Varshney, 2013). is:

$$NDBI = \frac{MIR-NIR}{MIR+NIR} \quad \text{Eq(7)}$$

Where, MIR refers is Mid-Infrared and NIR refers to Near-Infrared

$$NDBI = \frac{Band6-Band5}{Band\ 6+Band5} \quad \text{for Landsat 8 (Zhou et al., 2014)} \quad \text{Eq(8)}$$

3.3.3.3. Land Surface Temperature (LST)

Land surface temperature (LST) is an important factor in climate change, vegetation growth (Md Shahid, 2014). An emphasis is given in retrieving land surface temperature value for urban heat island (UHI) effect analysis. A split window method is used to retrieve LST values. This is because the method is applied by many scholars and most importantly it is less sensitive to the uncertainties in optical properties of the atmosphere; it is simple and computationally efficient and Landsat 8 data the thermal band has two bands (band 10: 10.6 µm to 11.2µm; band 11: 11.5µm to 12.5µm) which gives an advantage to apply the split window algorithm (Wan and Dozier, 1996; Rajeshwari & Mani, 2014; Chen et al., 2015). A split-window algorithm uses brightness temperature of two bands of TIR, mean and difference in land surface emissivity for estimating LST of an area. The process of acquiring LST value follows conversion of thermal infrared Digital Numbers (DNs) (band 10 and 11) to radiance or (TOA- Top of atmosphere) and to at-satellite brightness temperature.

Top of Atmosphere Spectral Radiance (TOA) can be calculated using the formula (Rajeshwari and Mani, 2014; [URL[17]]):

$$L_\lambda = M_L Q_{cal} + A_L \quad \text{Eq(9)}$$

Where:

L_λ = TOA spectral radiance (Watts/ (m^2 * srad * µm))

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_10/11)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_10/11)'

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Conversion to OLI TOA Reflectance

The following equation is used to convert level 1DN values to TOA reflectance (URL[18])

$$\rho\lambda' = Mp * Qcal + Ap \quad \text{Eq(10)}$$

Where;

$\rho\lambda'$: Top-of-Atmosphere (TOA) planetary spectral radiance, without correction for solar angle, $\rho\lambda'$is not true TOA because it doesn't contain a correction for solar elevation angle.

Mp: Reflectance multiplicative scaling factor for the land (REFLECTANCE_MULT_BAND_N rom the metadata).

Ap: Reflectance additive scaling factor for the land (REFLECTANCE_ ADD_BAND_N from the metadata).

$Qcal$: Level 1pixel value in DN

The conversion for true reflectance with corrected solar elevation angle is:

$$\rho\lambda = \rho\lambda' / \sin(\theta\epsilon) \quad \text{Eq(11)}$$

Where;

$\rho\lambda$: *corrected Top-of-Atmosphere Planetary Reflectance*

$\theta\epsilon$: Solar Elevation Angle.

URL[17] http://landsat.usgs.gov/Landsat8_Using_Product.php

URL[18] http://landsat.usgs.gov/documents/Landsat8DataUsersHandbook.pdf

TIRS Top of Atmosphere Brightness Temperature (TB) is the radiance travelling upward from the top of the Earth's atmosphere, and the process involves converting thermal DN values from thermal bands of TIR to TB (Weng, et al. 2004; Meng & Liu, 2013; Rajeshwari & Mani, 2014).

The formula used is:

$$TB = K2/\ln(K1/L\lambda + 1) \qquad \text{Eq(12)}$$

Where:

T = At-satellite brightness temperature (Kelvin)

L_λ = TOA spectral radiance (Watts/ (m^2 * srad * µm))

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_10/11)

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_10/11)

Calibration constants that are used during the execution of TOA Brightness Temperature are stated in the table below.

Table 6.TM and ETM+ thermal band calibration constants (Landsat 7 Handbook).

Satellite	Constant	Value
Landsat 5	K1	666.09
	K2	1282.71
Landsat 7	K1	607.76
	K2	1260.56

Table 7. Landsat 8 thermal band calibration constants.

category	Band 10	Band 11
K1	777.8853	480.8883
K1	1321.0789	1201.1442
Radiance_MULT_BAND	0.0003342	0.0003342
Radiance_ADD_BAND	0.1	0.1
Qcal	Band 10 DN	Band11 DN

Table 8. Split Window Algorithm constant values.

Constant	**Value**
C_0	-0.268
C_1	1.378
C_2	0.183
C_3	54.300
C_4	-2.238
C_5	-129.200
C_6	16.400

Table 9. Emissivity values.

Emissivity	Band 10	Band 11
ε_s	0.971	0.977
ε_v	0.987	0.989

Estimation of Fractional Vegetation Cover (FVC) is a method to get the fraction an area with vegetation cover using NDVI value. The researcher relied on estimating FVC for an area using the formula applied by Meng & Liu (2013), Siti et al. (2013), Md Shahid (2014) and Rajeshwari & Mani (2014).

The formula is:

$$FVC = \frac{NDVI - NDVIs}{NDVIv - NDVIs} \quad \text{Eq(13)}$$

Where, NDVI is Normalized Difference Vegetation Index, NDVIs is NDVI for soil and NDVIv is NDVI for vegetation. NDVIs and NDVIv can be obtained through rectifying NDVI using ArcGIS 10.3 software. The FVC estimation is calculated in ERDAS IMAGINE 2014 Modeler.

For Single Window Algorithm calculation a Proportional Vegetation can be analyzed using the following formula:

$$Pv = ((NDVI - NDVImin)/(NDVImax - NDVImin))^2 \quad \text{Eq(14)}$$

Where, Pv refers to Proportion of Vegetation.

For estimation of Land Surface Emissivity in the Single Window Algorithm, the following equation is applied:

$LSE = 0.004 * Pv * 0.986$ (Sobrino et al., 2004) Eq(15)

Estimation of Land Surface Emissivity (LSE) is important to understand the inherent characteristics of the earth's surface and to change the thermal or heat energy to radiant energy to calculate LST. The emissivity constant values for soil and vegetation are stated in table 3.9. Md Shahid (2014) and Rajeshwari and Mani (2014) applied the following formula to obtain LSE.

$$LSE = \varepsilon s * (1 - FVC) + \varepsilon v * FVC \qquad \text{Eq(16)}$$

Where, εs refers to Emissivity for soil, εv refers to Emissivity for vegetation and FVC refers to Fractional Vegetation Cover.

Depending on LSE estimation formula LSE for band 10 and band 11 are computed. Using the result mean and difference value will be generated which is used in LST computation. Therefore, Mean of LSE and Difference of LSE of band 10 and 11 are calculated as follows.

$$Mean\ LSE = m = \frac{LSEb10 + LSEb11}{2} \qquad \text{Eq(17)}$$

$$Difference\ of\ LSE = \Delta m = LSEb10 - LSEb11 \qquad \text{Eq(18)}$$

As a result, LST using Landsat 8 satellite data, estimation is implemented with the Split Window Algorithm by ERDAS IMAGINE 2014 and ArcGIS 10.3. The constant values, C1–C6 are given in table 3.8 and used in retrieving LST. The formula is given according to Md Shahid (2014) and Rajeshwari & Mani's (2014).

$$LST = LST = TBb10 + C1(TBb10 - TBb11) + C2(TBb10 - TBb11)^2 + C0 + (C3 + C4W)(1 - m) + (C5 + C6W)\Delta m \qquad \text{Eq(3.17)}$$

Where,

TB_{b10} and TB_{b11} – Brightness Temperature of Band 10 and 11

C_0-C_6 – Split-Window coefficient values (Table 3.8) (Md Shahid, 2014; Rajeshwari and Mani, 2014)

m – Mean LSE

Δm – Difference of LSE

W – Atmospheric water-vapor content (0.004, which was acquired using a conversion table depending on the measured temperature values URL[19], URL[20]).

Estimation LST using Single Window Algorithm can be done using the formula:

$$LST = TB/(1 + \left(W * \frac{TB}{P}\right) * \ln(e)) \qquad \text{Eq(19)}$$

Where,

TB – At Satellite Temperature of Landsat 5 and 7.

W – Wavelength of emitted radiance (for Landsat TM 11.457, for Landsat ETM+ 11.269).

P – h*c/s (P=14380)

h – Planck's Constant

s – Boltzmann Constant

c – Velocity of light

3.3.3.4 Park cooling distance

Temperature measurements within/or inside the selected 8 parks and outward from the boundary of the parks to the settlement areas to a distance of 30m for 5 locations and in total the measurement covers 150m distance. The minimum and maximum temperature measurements were taken from the park boundary to the surrounding. In addition, the month of March was taken for collecting field data, because this month is found in winter season and recorded with high temperature, where precipitation and cloud cover has little/no influence on having clear sky radiation. Furthermore, from 12 Noon to 2:00 pm time was considered as an appropriate time to collect data due to the angle of the sun, where shadow of high buildings has little or no influence on the ground area.

URL[19] http://www.regentsearth.com/Illustrated%20ESRT/Page%2012%20(DP%20&%20RH)/ESRT%20page%2012%20index.htm

URL[20] file:///C:/Data/5rs_3_2-3.pdf

The standard time (response time) used to record the value of air temperature on the field using Psychrometer is 20 second (WMO, 2008). The instrument was handled by the researcher at a height of 1.25m above the ground and the measurement was taken.

Regarding measuring air temperature in urban environment (cities), the instrument has to be located 5 to 10 meter away from buildings. Conditions were considered with regard to the open field between buildings.

International standards were set for measuring field temperature. World Meteorological Organization (WMO) (WMO, 2008) suggests Psychrometer for field temperature measurements. Psychrometer is the reference instrument for determining the relationship between the air temperature measured by conventional surface instruments and the true air temperature. Psychrometer is a free standing instrument.

Eight parks, as shown in table 3.10, were selected for the park cooling distance analysis and to correlate with the land surface temperature around the parks. For correlation purpose, Zonal statistics and a regression model was considered between public parks and NDVI and also with LST results. At Sheger Park the temperature was measured at three different times, from 6:00am to 7:00am (morning), 12 Noon to 2:00pm and 6:00pm to 7:00pm evening.

Application of field temperature measurement was very helpful to notice the park influence to the surrounding area through mediating the atmospheric temperature (Gudina Legesse et al., 2014). The framework of the study is schematically given in Fig.3.8.

Table 10. Sampled parks for the research study.

No	Name of Park	Sub City	Area (m^2)	Area (%)
1.	Gedame Eyesus	Addis Ketema	4,128	1.28
2.	Ambassador	Arada	9,393	2.90
3.	Sheger	Gulele	70,000	21.63
4.	Africa	Kirkos	45,707	14.12
5.	Kolfe	Kolfe Keraniyo	20,000	6.18
6.	Gola	Lideta	9,625	2.97
7.	Bihere Tsige	Nefas Silk Lafto	142,726	44.10
8.	Yeka	Yeka	22,081	6.82
		Total Area	**323,660**	**100**

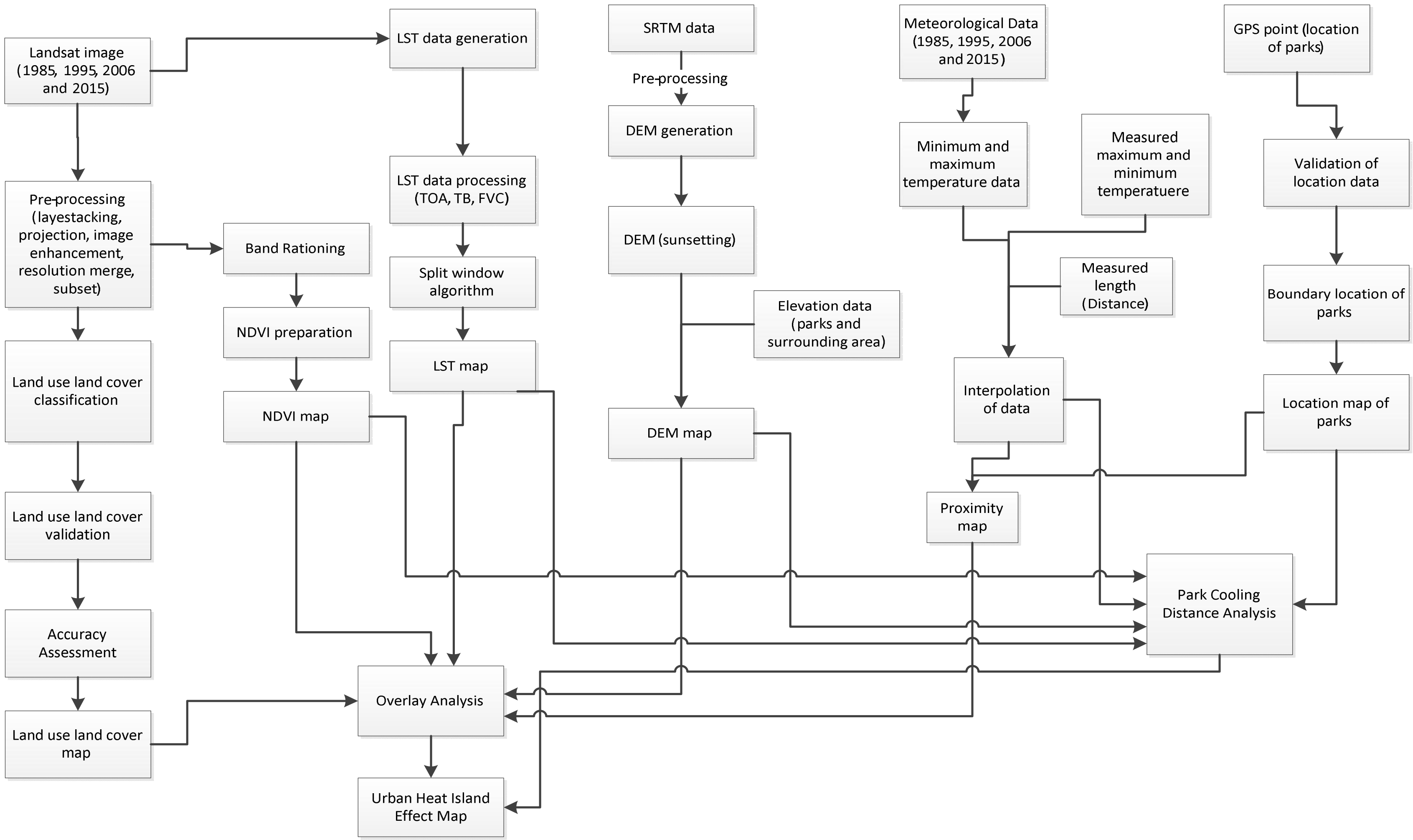


Figure 8. Schematic framework of the Methodology.

CHAPTER IV

RESULTS

4.1. Public Parks

In the study area 19 public parks are existed. These parks were expected to give recreational services to public. Total area covered by public parks is 931, 086 m^2. Peacock Park covers 39.1% and Bihere Tsige park accounts for 15.33%. In contrast to this, Kaleb Park constitutes 0.14%. Out of the 19 public parks 68.42% of them are committed to give services to the public, 13 public parks. The remaining percentage of parks, because of re-development and assigning to other services, were not able to give the desired service to the public. In the context of sampled parks, Bihere Tsige constitutes 44.1% of area coverage. The least in size is Gedame Eyesus Park and covers 4,128m^2, which is 1.28%. Since the size of each park varies, their area covered by vegetation also varies. All public parks including sampled parks were mapped and their tabular data is given in Fig. 9 and appendix 4 respectively.

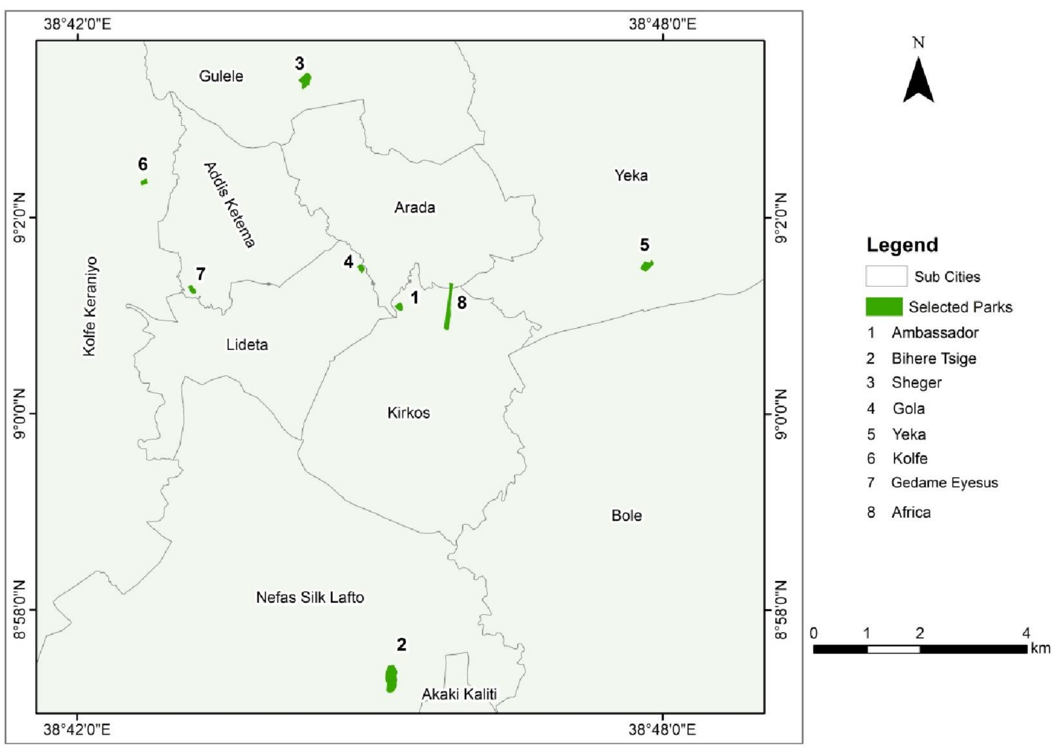


Figure 9. Distribution map of selected parks.

4.2. Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index result for each selected park for the specified year is indicated in Fig.10, and Table 11. The NDVI value of year 1985 ranges from -0.15 to 0.68 was found and the value 0.68 depicts the area under vegetation cover. The value close to -1, which is -0.08, indicates a bare land, or an open area, or a water body. This is due to the variation in reflectance each surface features. The 1985, 1995, 2006 and 2015 NDVI value ranges from -0.15–0.68, 0.17–0.71, -0.2–0.78 and -0.27–0.65 respectively. The average NDVI of the four study base years was 0.55. The area under vegetation cover can be identified in the Northern part of Addis Ababa, where Entoto Mountain is located, along with the river banks and a place like urban green areas where vegetation exists.

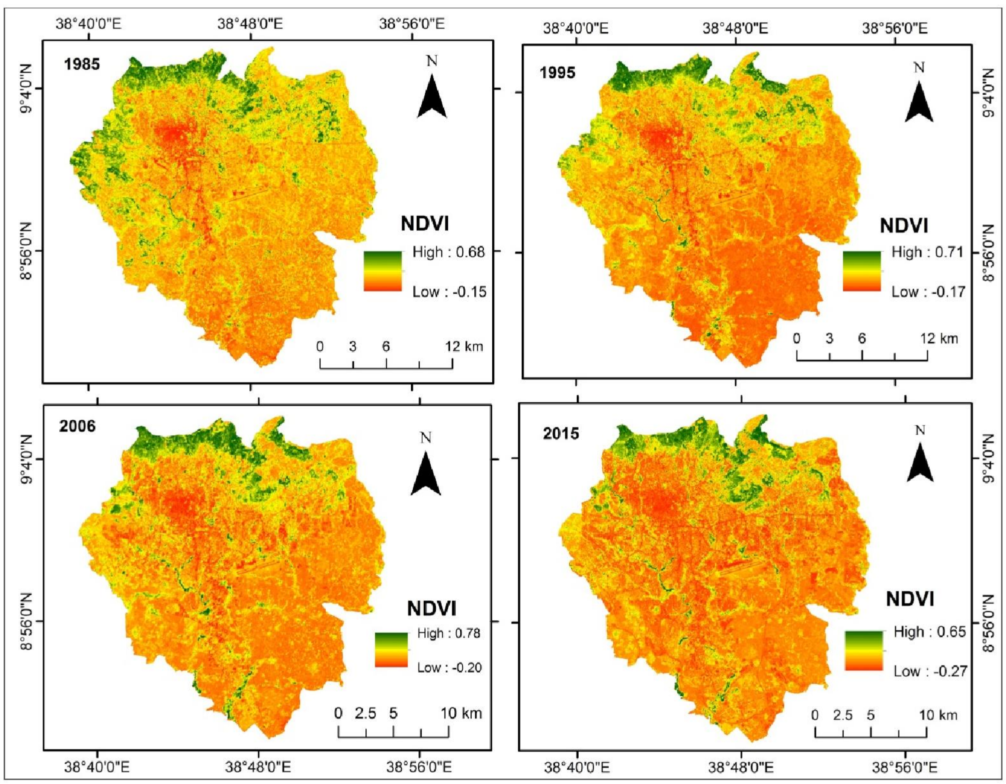


Figure 10. Normalized Difference Vegetation Index map of the study area.

Table 11. Normalized Difference Vegetation Index of Parks for 1985 (A), 1995 (B), 2006 (C) and 2015 (D).

Public Parks	Min				Max				Mean				Standard Deviation			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Ambassador	0.2	0.2	0.3	-0.1	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1
Bihere Tsige	0.2	0.2	0.3	-0.2	0.6	0.6	0.7	0.5	0.5	0.4	0.5	0.2	0.1	0.1	0.1	0.2
Sheger	0.2	0.2	0.3	-0.1	0.6	0.5	0.7	0.2	0.4	0.4	0.5	0.1	0.1	0.1	0.1	0.1
Gola	0.2	0.2	0.1	-0.01	0.3	0.4	0.4	0.3	0.2	0.2	0.3	0.1	0.04	0.1	0.1	0.1
Yeka	0.2	0.2	0.2	-0.1	0.5	0.5	0.5	0.2	0.3	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Kolfe	0.2	0.2	0.2	-0.2	0.5	0.4	0.4	0.2	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Gedame Eyesus	0.2	0.2	0.1	-0.1	0.3	0.4	0.5	0.3	0.2	0.3	0.3	0.1	0.02	0.1	0.1	0.1
Africa	0.1	0.04	0.1	-0.2	0.5	0.4	0.5	0.4	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1

Bihere Tsige Park covers 44.10 % out of the total selected parks 323,660 m^2 area. The NDVI maximum value of Bihere Tsige Park in the given table 11 and exceeds 0.6, in the year 1985 and 1995 respectively. The smallest in area coverage is Gedame Eyesus Park, 1.28% out of the total. Its' NDVI maximum value in 1985 is below 0.3 and in 1995 is about 0.35. This shows that, park extent and shape has an impact on influencing the NDVI value. The largest the extent and vegetation coverage, is the positive the value that close to 1.

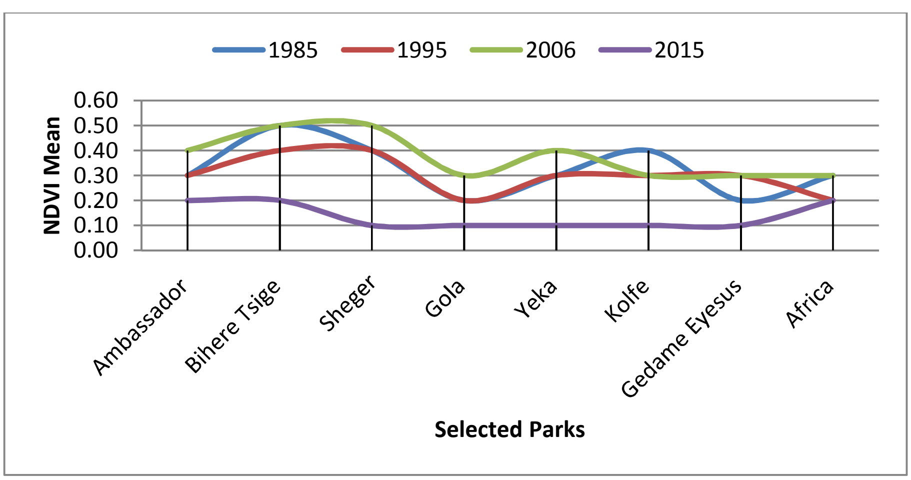


Figure 11. Mean Normalized Difference Vegetation Index for the year 1985, 1995, 2006 and 2015.

4.3. Normalized Difference Built Up Index

The built-up index in the figure 12 indicates that, the positive values can define the area under built-up is strong. LST is the increase in temperature value, which is due to the high reflectance of the surface structures, is the high the temperature. The expansion of urban built-up areas has a significant influence on the surface temperature. The positive value from the Fig. 12 illustrates the potential of the area to be under built-up. The color contrast which is visible in the Normalized Difference Built-Up Index map of 1985, 1995 and 2006 clearly shows the concentration of the built-up area, rather than the 2015 map. This is due to the variation between the class values, which is widening in the 2015 NDBI map. However, in the Fig. 12, the area under dark blue depicts no built-up existence.

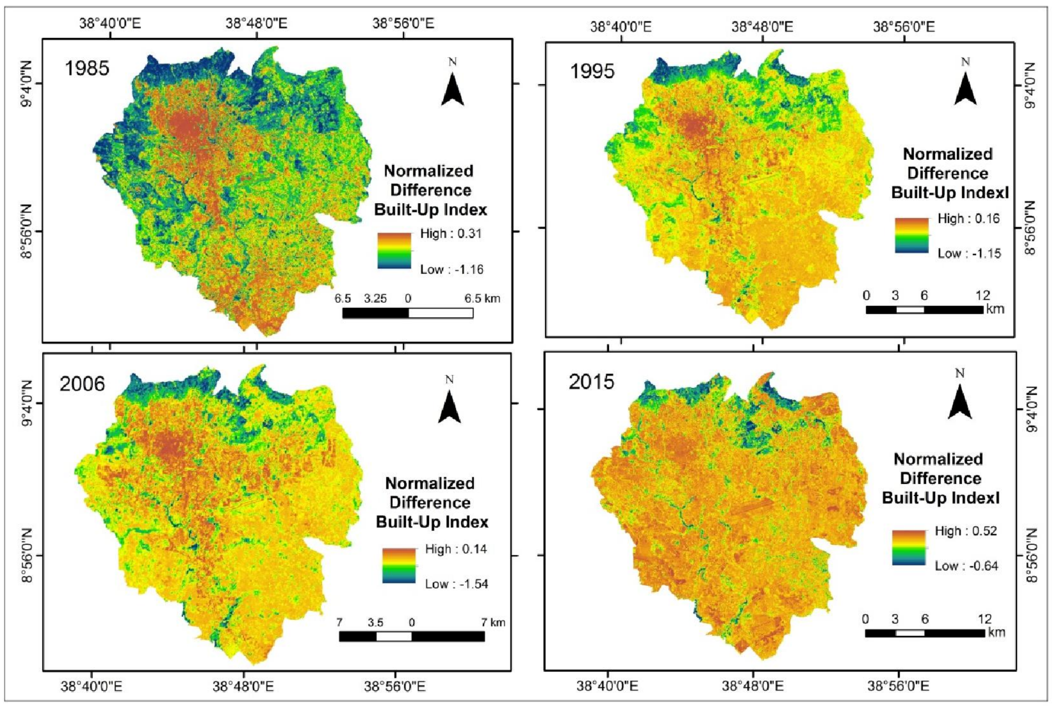


Figure 12. Normalized Difference Built-Up Index map for the year 1985, 1995, 2006 and 2015.

4.3. Results of Land Surface Temperate

In the figure 13 shows the Land Surface Temperature variations in 1985, 1995, 2006 and 2015. The minimum temperature for all four years can be identified in the

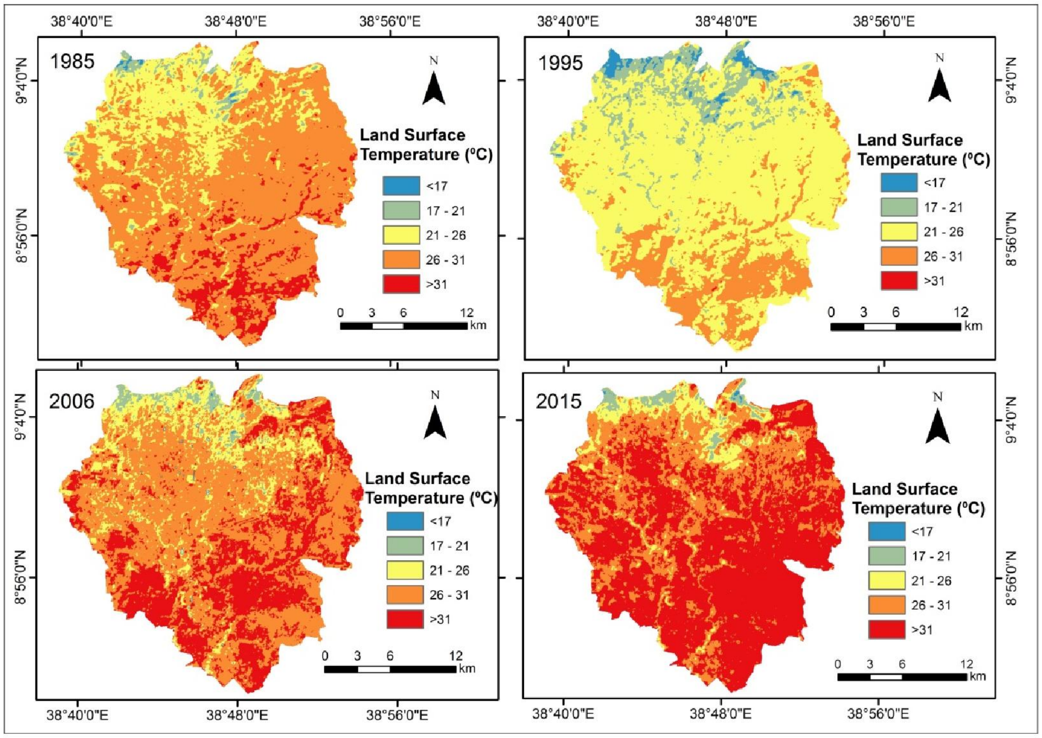


Figure 13. Land Surface Temperature for 1985, 1995, 2006 and 2015

Northern part of the study area where the vegetation cover is high, in the parks and around the river banks, where riverine vegetation existed. The Land Surface Temperature variations can be clearly identified from the map in Fig. 13 In 1985 the large part of Addis Ababa is dominated by temperature between 26 °C and 32°C. These areas are dominated by built up, bare agricultural areas, bare land, which exhibited a high surface reflectance. Figure 16, clearly indicates the Land Surface Temperature received by each selected year for the study area. A maximum surface temperature of 40°C in 2015 and 36.5°C in 1985 were observed. Grid meteorological temperature data collected from 4 stations in Addis Ababa, the recorded monthly average temperature is indicated in table 12. The monthly average maximum temperature for the year 1985 (table 12) is 24.1°C, while the LST value is above 32 °C. However the minimum temperature for the same year according to table 4.2 is 9.3°C and the LST is 13°C.

Table 12. Meteorological Temperature Data

Temperature °C	Period			
	1985	1995	2006	2015
max	24.1	25.6	26.1	26.3
min	9.3	10.6	11.1	11.7
mean	16.7	18.1	18.6	19

Source: National Meteorological Agency, Ethiopia (2016)

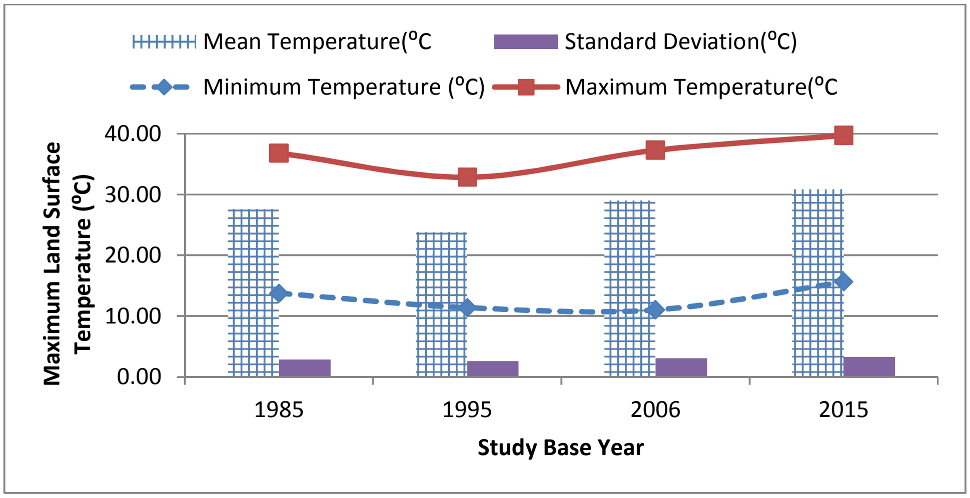
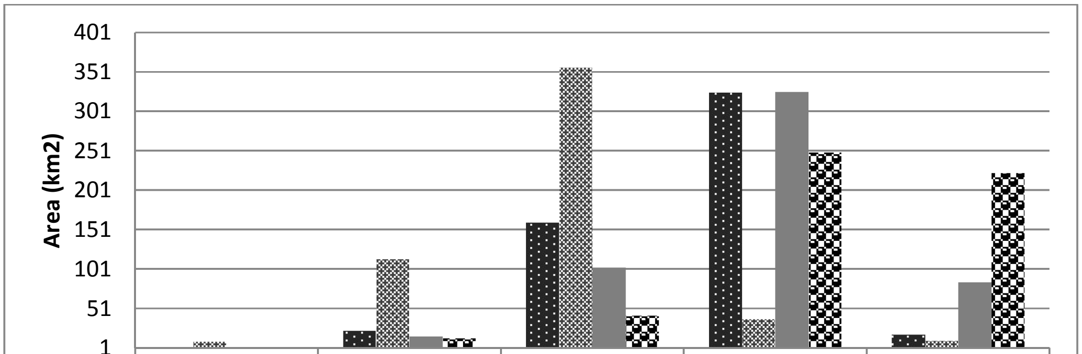


Figure 14. Land Surface Temperature Variations

In 1985 out of the 8 selected public parks, 75% of them received above 25°C maximum surface temperature. In addition, Sheger Park exhibited the minimum surface temperature, below 20°C. The minimum LST observed in the year 1985 is 13°C, whereas, in 1995 about 11°C, 9°C in the year 2006 and in 2015 was 15°C. The maximum surface temperature was seen in the year 2015 and is about 39.75°C. The minimum surface temperature in 2006 exceeds by 6°C and become 15°C in 2015. The maximum temperature in 1985, 36.83°C, in 1995 were32.85°C, in 2006 was about 37.75°C and in 2015 was about 39.75°C.

Land Surface Temperature derived for each study year shows the variation in area coverage with the classified temperature class (Fig. 15). As a result, in 1985 less than 17 °C temperature covers 0.95km^2, in 1995 is about 9.06km^2, in 2006 was 0.17km^2 and in 2015 was 0.34km^2. Surface temperature value greater than 31°C in 1985 covers 18.28km^2 of area, in 1995 about 10.12km^2, in 2006 was 83.75km^2 and in 2015 estimated as 222.46km^2 area coverage. Likewise, other surface temperature classes with their defined area coverage were stated in Fig. 15.



	<17°C	17–21°C	22–26°C	27–31°C	>31°C
1985	0.95	22.94	159.82	324.48	18.28
1995	9.06	113.84	355.89	37.57	10.12
2006	0.17	15.30	102.35	324.90	83.75
2015	0.34	13.25	41.85	248.57	222.46

Figure 15. Land Surface Temperature Coverage for 1985, 1995, 2006 and 2015.

The LST result shows that, the minimum temperature received by Sheger Park is below 20°C. The maximum surface temperature of Sheger Park was 26.25°C. Ambassador Park in 1985 received 24.9 °C and 27.1°C minimum and maximum surface temperature respectively. However, Bihere Tsige park 21.9 °C and 27.5 °C of minimum and maximum land surface temperature respectively. In 1985, Gola and Yeka park respectively exhibited 24.9 °C and 25.4 °C minimum, and 25.4 °C and 28.4 °C maximum Land Surface Temperature. Furthermore, Kolfe Park in the year 1985 noticed surface temperature of 23.7 °C minimum and 24.5 °C maximum. On the other hand, Gedame Eyesus and Africa Park respectively showed 24.1 °C and 22.8 °C minimum, 26.7 °C maximum. The mean LST of each park is given in Figure 16.

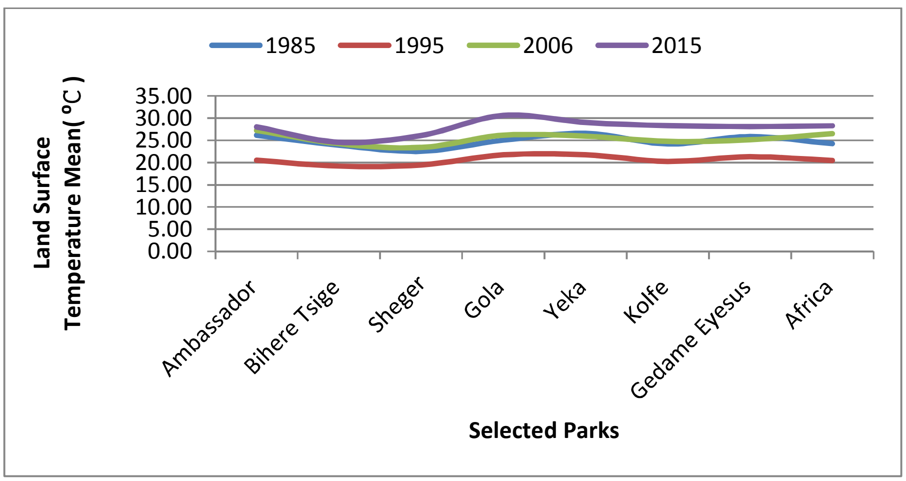


Figure 16. Mean Land Surface Temperature of selected Public Parks.

Therefore, the mean surface temperature of Ambassador park was 20.5 ^oC, Bihere Tsige park 19.2 ^oC, Sheger park 19.5 ^oC and Gola Park 21.7 ^oC. Yeka and Kolfe Park respectively received 21.8 ^oC and 20.3 ^oC of mean temperature. In addition, the mean temperature for Gedame Eyesus Park was 21.3 ^oC and Africa Park was 20.5 ^oC.

With reference to the 1995 LST result, more than 85% of the parks received above 20^{0}C of surface temperature at the time. The maximum surface temperature was seen in Bihere Tsige Park and where the minimum surface temperature is also received there. The effect of vegetation cover over an area can be clearly seen in the measured maximum and minimum temperature, where the amount of vegetation cover over an area decreases, the highest the surface temperature and the little the difference between maximum and minimum surface temperature.

In the table 133 below shows the surface temperature received by each selected park in the year 2006 was clearly indicated. As a result, the highest mean temperature have been noticed in Ambassador park, which is 27.24^{0}C. Whereas, the lowest mean surface temperature relative to each park was 23.39^{0}C, in Sheger Park.

Table 13. Land Surface Temperature for sampled parks of year 2006

Park Name	Minimum T^{0}C	Maximum T^{0}C	Mean T^{0}C	St.D
Ambassador	26.86	28.82	27.24	0.61
Bihere Tsige	21.30	29.31	24.25	2.34
Sheger	20.26	27.84	23.39	2.20
Gola	24.36	28.33	26.15	1.22
Yeka	23.35	30.75	25.94	2.07
Kolfe	23.35	26.36	24.76	1.05
Gedame Eyesus	23.86	26.36	25.13	0.88
Africa	22.84	29.79	26.50	1.85

In 2015, the Land Surface Temperature of the selected park was indicated in table 14. The maximum surface temperature for Ambassador and Bihere Tsige Park was 30.3^{0}C and 29.18^{0}C respectively. Sheger Park received 30.53^{0}C and Gola Park 32.36^{0}C of maximum temperature. The remaining Yeka, Kolfe, Gedame Eyesus and Africa Park respectively received 32.92^{0}C, 30.5^{0}C, 29.97^{0}C and 30.99^{0}C.

Table 14. Land Surface Temperature for selected parks of year 2015

Park Name	Minimum T⁰C	Maximum T⁰C	Mean T⁰C	St.D
Ambassador	25.40	30.30	28.04	1.60
Bihere Tsige	22.44	29.18	24.57	1.69
Sheger	23.25	30.53	26.10	1.75
Gola	29.51	32.36	30.62	0.99
Yeka	26.87	32.92	29.03	1.58
Kolfe	26.64	30.50	28.30	1.15
Gedame Eyesus	26.97	29.97	28.12	0.77
Africa	24.61	30.99	28.28	1.79

4.4. Land Surface Temperature and Land-Use/Land-Cover change

The Land Surface Temperature values for the Land-Use/Land-Cover classes of the study year are shown in Fig. 17. The maximum temperature, above 35⁰C was exhibited within built up, bare land, grass land and agricultural land. Hence, the satellite image was taken in January 1995; it is characterized by dry weather conditions. Due to this, surface reflectance in agricultural areas was higher and instead increases surface temperature. A little decrease in the amount of surface temperature seen in the period 1995, which is even high.

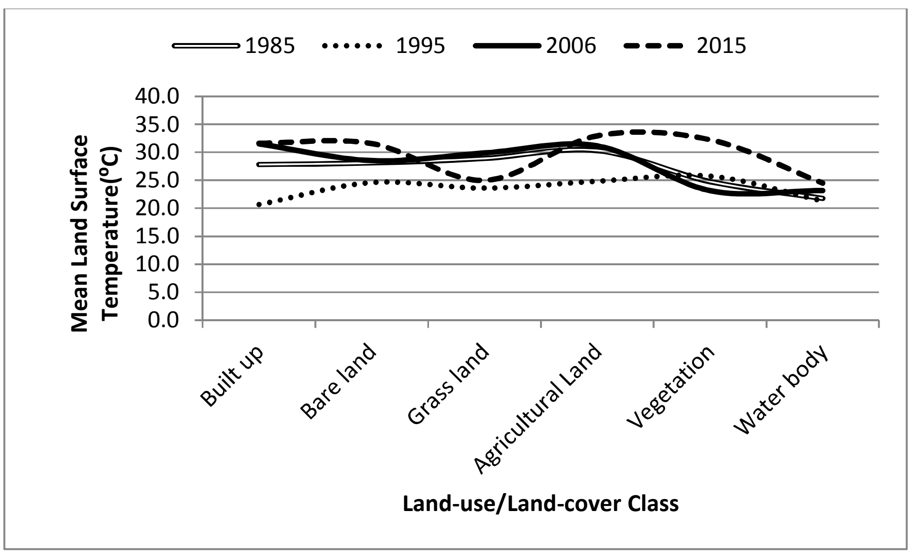


Figure 17. Land-use/Land-cover classes with Land Surface Temperature relationship.

Table 15. Land Surface Temperature and Land-use/Land-cover relationship for 1995.

Land-use/Land-cover class	Minimum T°C	Maximum T°C	Mean T°C	Standard Deviation
Vegetation	11.41	30.01	20.67	2.94
Bare land	12.36	32.46	24.60	1.81
Built-up	13.31	32.86	23.61	2.25
Grassland	17.02	32.46	24.84	1.65
Agricultural land	17.02	32.46	25.74	1.35
Water Body	17.48	26.25	21.32	2.48

The land-use/land-cover class that received the highest maximum temperature was Built-up area. Whereas, green vegetation covered areas received LST of above 35^{o}C. Relatively the lowest mean LST was recorded by Water body and green vegetation class.

In analyzing the land-use/land-cover and land surface temperature relationship, table 16 Shows that, the lesser the mean temperature is recorded in the class vegetation and water body, which is 23.16^{o}C and 23.17^{o}C respectively. The highest mean temperature was received by Grassland, 31.52^{o}C and Cropland, 31.15^{o}C. However, Built-up and Bare land areas respectively recorded with 28.52^{o}C and 29.89^{o}C surface temperature.

Table 16. land Surface Temperature and Land-Use/Land-Cover relationship for 2006.

Land-use/Land-cover class	Minimum T°C	Maximum T°C	Mean T°C	Standard Deviation
Grassland	21.30	36.84	31.52	1.67
Built-Up	9.89	37.75	28.52	2.60
Bare land	19.74	36.38	29.89	2.02
Agricultural land	19.74	37.75	31.15	1.58
Vegetation	15.47	34.53	23.16	2.89
Water Body	21.30	26.86	23.17	1.09

The Land-use/Land-cover change of the study area from 1985 to 2015 shown in the table 17 and also in Fig. 18.

Table 17. Land-Use-/Land-Cover Change.

Land-use/Land-cover class	1985		1995		2006		2015	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Vegetation	87.342	16.6	82.189	15.61	68.299	12.97	50.21	9.54
Bare land	49.735	9.4	47.97	9.11	40.21	7.64	31	5.89
Built-up	135.146	25.7	213.125	40.48	254.31	48.31	314	59.64
Grassland	48.324	9.2	32.83	6.24	25.187	4.78	15.79	3
Agricultural land	205.669	39	150.12	28.51	138.2	26.25	115	21.84
Water Body	0.254	0.1	0.236	0.05	0.264	0.05	0.47	0.09

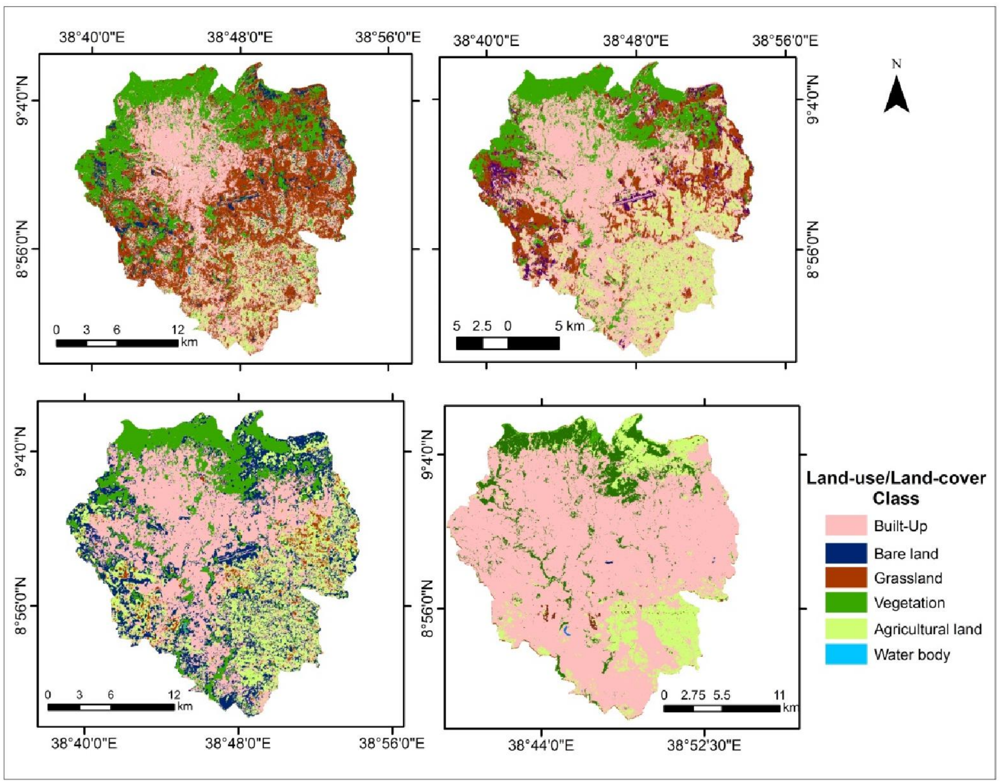


Figure 18. Land-use/Land-cover maps for 1985, 1995, 2006 and 2015.

Table 18. Accuracy Assessment Report for Land-use/Land-cover classification

Accuracy Assessment	1985	1995	2006	2015
Overall Classification Accuracy	92.58%	90.63%	91.02%	92.97%
Kappa Statistics	0.9084	0.881	0.8494	0.9021

4.4.2. Land Surface Temperature and Normalized Difference Vegetation Index

The indirect relationship between LST and NDVI can be found positive from the analyzed 1985, 1995, 2006 and 2015 Landsat data. The R^2 values indicated on the stated year between LST and NDVI correlations show that, 79.93%, 76.33%, 79.25% and 84.19% respectively. These values indicates that, the percentage value (79.93%) of LST (1985) variability is due to the variation in NDVI value, the coefficient variation values are true for the remaining year. Furthermore, the increased in the value of NDVI, which is the high the vegetation cover, the lower or decrease in the amount of surface temperature. This correlation is said to be indirect and negative. When the correlation is said to be negative, it refers not to the weakness of the correlation, rather it describes the decrease in the amount of NDVI values, it the increase in the LST value.

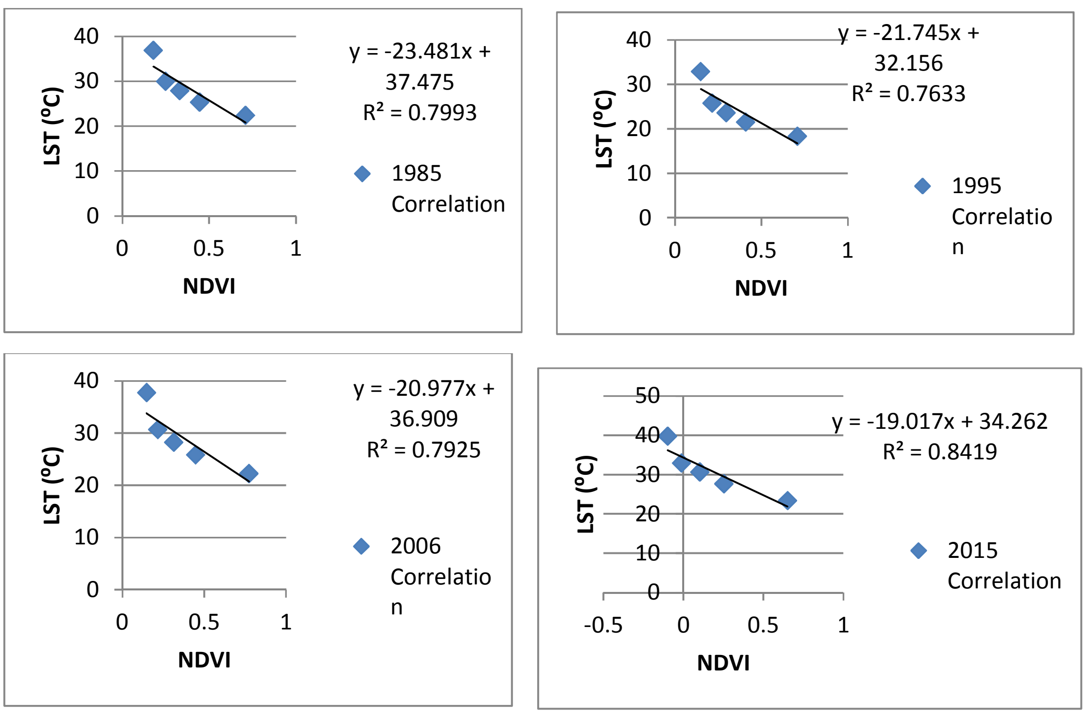
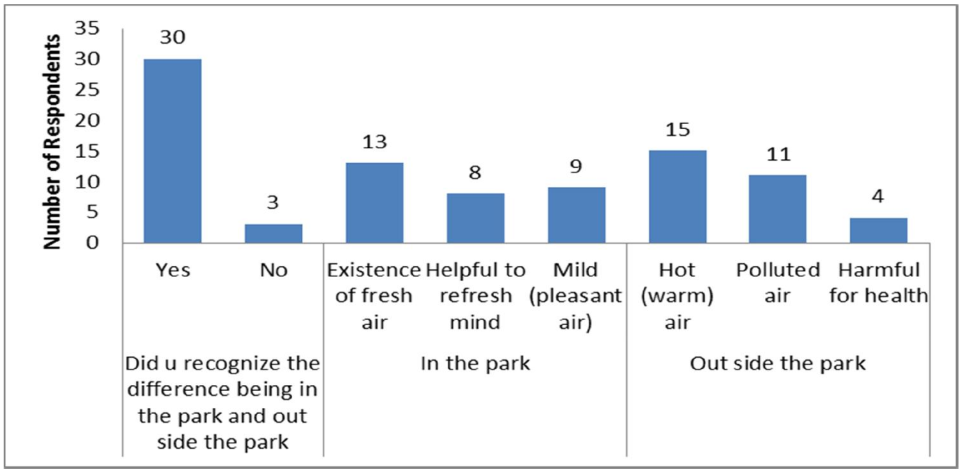


Figure 19. NDVI and LST correlation in 1985, 1995, 2006 and 2015.

4.7. Efficiency of Public Parks on mitigating Urban Heat Island Effects

On the selected 8 public parks 33 people were given a questionnaire with regard to the public park they are visiting. This questionnaire is given to respondents to collect their perceptions towards urban green areas. Out of the total respondents 90.9% recognizes the difference being in the park and the environment outside the park. The statistical data shows that, people are aware of the benefits of the existence of parks within the community. While defining the condition within the park, 43.33% of respondents believe there exists a fresh air, which necessary for the health. Surrounding the park and getting



far from the park, the influence of the park decreases. As a result, the respondent identified a warm and polluted air outside the park. Hence, this warmth of the atmospheric condition has an effect on people's health, affects living condition of the society and hinders the overall socio-economic condition of the dwellers.

Figure 20. Understanding the difference inside and outside the park.

Due to the benefits of the public parks, people tend to visit at different time and occasions. Fig. 21.. Shows that, 37% of the respondents tend to visit parks once in a weak, followed by 24% those who visit sometimes and 12 % weekends. 3% of the respondents visit the public parks once in a month. Since, the number of respondents varies with visiting time; all of them understand the importance of visiting those public parks.

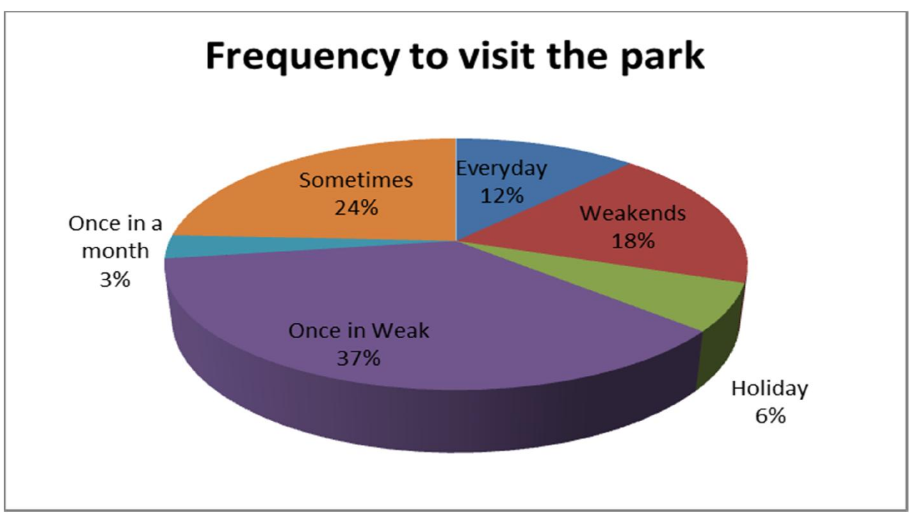


Figure 21. Frequency of visiting in sampled public parks.

The efficiency of parks on mitigating the UHI effect is enormous. The temperature difference within the sampled public parks and outside the parks were measured using the dry and wet bulb whirling Psychrometer. In the appendix 4, the measured amount of temperature (°C) at each park for a distance of 150 meter was given. In general, the measured result (Fig. 22) shows that, the amount of temperature recorded from the park center to a 30 meter distance at 5 stations results in an increase. With increasing distance the cooling of effect of parks also decreases.

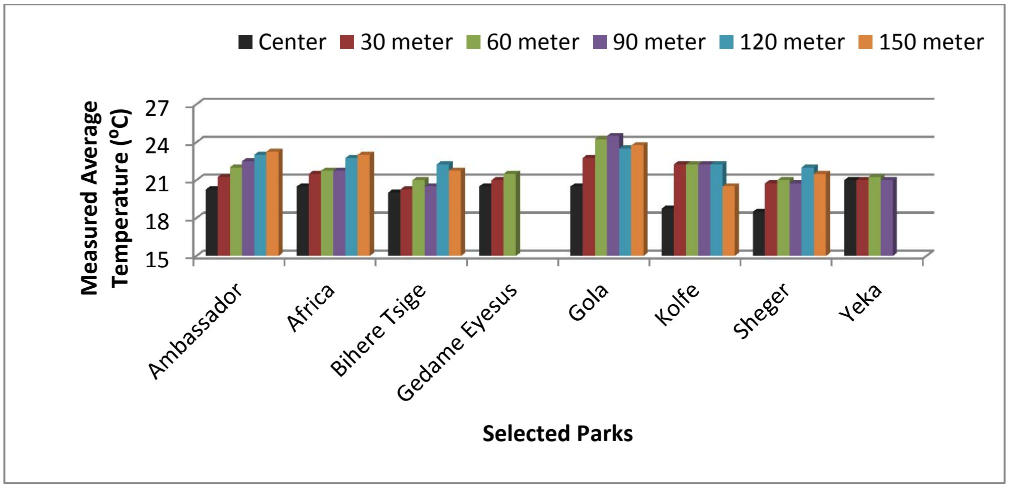


Figure 22. Measured temperature at some distance from the parks.

Throughout those parks, the measurement shows that the amount of temperature increases at minimum 1°C at Yeka Park and 5°C at Ambassador Park. Measuring temperature out the parks of Gedame Eyesus and Yeka, the surrounding temperature hinders for further measurement after 60 meter distance from the park.

The final overplayed Urban Heat Island Map of Addis is indicated in Figure 23.

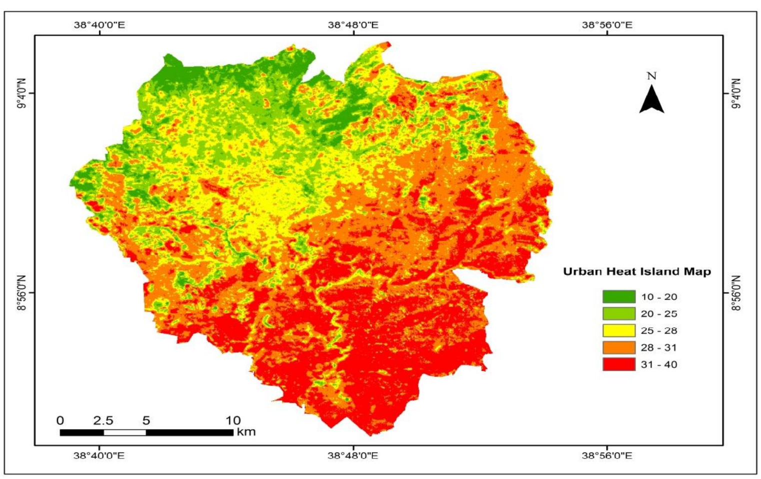


Figure 23. Urban Heat Island Map.

CHAPTER V

DISCUSSIONS

5.1. Normalized Difference Vegetation Index.

NDVI is used as an indicator of LST in several researches. According to Weng et al. (2004), NDVI is found as an acceptable indicator of LST. Where, the coefficient variation determination value of NDVI account for 74.18% of variance in the Land Surface Temperature distribution. The 2015 NDVI and LST correlation of Addis Ababa indicates that, the correlation coefficient of NDVI accounts for 84.19% of the LST distribution. The R^2 value indicates a strong relationship in between NDVI and LST.

5.2. Land Surface Temperature

A study conducted in Patna Municipal Corporation in India by Ashraf (2015) focused on analyzing the LST of the municipal from 1989–2014 for six base years and the result shows that the minimum temperature which is 19.584°C on February 1993, has increased gradually to 22.055°C on February 2014. In this study the result found that, the minimum surface temperature in 1985 was 13°C, 11^oC in 1995, 9^oC in 2006 and 15°C in 2015.

Measured temperature values in the park and outside the park varies, that the influence of the vegetation covers in the park decrease with an increase a distant from the park. The findings in the study conducted by Cheng et al.(2015) indicated that, the highest mean LST 36.15^oC, was observed within the smallest park and the lowest mean LST 31.25^oC recorded within the second largest park. In this study the highest mean temperature was observed in Gola, Gedame Eyesus and Africa Park which was 20.5^oC. The lowest temperature was recorded in Sheger Park, 18.5^oC. The larger the size of the park, the decrease in the amount of temperature received. The larger the area of the park, the more likely to be cooler or be efficient in cooling the surrounding environs.

The statistical correlation between the land-use/land-cover classes and LST in 1985 indicates that, the lowest mean temperature was observed on water body, which was 22^oC and the highest was recorded by Agricultural land and it was 30^oC.

5.3. Normalized Difference Built-up Index

These indices are applicable to notice the changes in the built-up environment. Varshney (2013) applied the NDBI algorithm to conduct change detection between the year 2000 and 2010 in the built-up environment. Xu (2007) also applied the NDBI for analyzing the built-up area using the NIR and Red band. The rapid urbanization problem has brought many environmental problems such as the development of UHI and the change in land use/land cover (Feinzizadeh and Blaschke, 2013).

The study conducted by Zha et al. (2010) indicates that, the application of NDBI in identifying the general built-up area is effective. Even if the reflectance of built-up and bare land is similar and the NDBI considers both as the same value, it has an advantage to show the high reflectance area for Land Surface Temperature analysis. With this study, it also found that, the NDBI values for the year 1985, 1995, 2006 and 2015 which are positive indicates the area under the influence of built-up area. Ramdani and Setiani (2014) in their research called spatio-temporal analysis of urban temperature in Bandung City; they used NDBI as a tool to indicate the urban temperature. As a result, they found a positive correlation between NDBI and urban temperature. This implies that, NDBI has an additive effect on the urban temperature. This is due to the surface structures existed in urban areas which instead increases reflectance.

Normalized Difference Built-up Index is used as a indicator to urban expansion in Marcia City in Brazil (Souza, 2015). Souza (2015), discussed that the application of temporal data's in NDBI can be used to analyze urban sprawl.

5.4. Land-use/land-cover change

Maitima et al. (2009) studied the linkage between land use change, land degradation and biodiversity across East Africa, noticed that, land covers were transformed to farmlands, grazing land and human settlements at the expense of the natural vegetation. With regard to land-use/land-cover change in the study area, with the expansion of the built-up area the vegetation cover, as well as the agricultural land decreased.

A study conducted by Amanuel Abate and Mulugeta Lemenih (2014) in South Western Ethiopia of Nadda Asendabo watershed, the area predominantly covered by forest in 1973 and 1986 were gradually decreased in area by the expansion of agricultural land and built-up area. In this study, the area under vegetation cover in 1985 was 16.6%, but recently the satellite image shows that, the amount decreased to 9.54%. The land under built-up in 1985 and 2015 respectively found 25.7% and 59.64%. This indicated that there is a change in land-use/land-cover

5.2. Urban Heat Island

Several of researches conducted on analyzing UHI, depend on generating LST, which shows the relative warmth of cities through measuring the air temperature, using land based observation stations (Ashraf, 2015). Weng et al. (2004), executed a research in

Indianapolis shows that the hot spot areas are identified in central business districts, and small hot spot areas or urban heat islands identified along the road, where built up areas are densely existed and the highest temperature, 32.14ºC exhibited in commercial and industrial areas. Likewise, results on LST of Addis Ababa shows the hot spot areas are located in the center where settlements are congested. And also business complexes are built along the road side, where the highest temperature observed. The mean surface temperature of Addis Ababa in 1985 is about 27.65ºC and this observed temperature increased to 30.9ºC in 2015.

5.3. Urban Parks on mitigating Urban Heat Island

Urban Parks are considered as Urban Green Belts with diversified benefits to the dwellers. Chiesura (2003) studied the role of urban parks for the sustainable city and stated that, important environmental services such as air and water purification, wind and noise filtering, or microclimate stabilization, natural areas provide social and psychological services, which are of crucial significance for the livability of modern cities and the wellbeing of urban dwellers. With reference to this study, 33 induvial were given a questionnaire and responded that, the public parks have the ability to moderate the warm temperature, gives a fresh air which is a natural medicine for health. The measured data's indicate that, a minimum 1ºC and a maximum of 5ºC temperature increase when one goes away from the public parks (Figure 4.15).

CHAPTER VI

CONCLUSION AND RECOMENDATION

5.1. Conclusion

The advancement of Remote Sensing and Geographic Information system become convincing towards analyzing the environment we are living today, in front of our desktop.

In this research these two technologies were used in pre-processing the satellite images, producing a data for output generation. Landsat data for the year 1985 and 1995,Landsat TM; for 2006 Landsat ETM+ and for 2015 Landsat 8 were used. Image pre-processing such as radiometric and geometric corrections are very important in minimizing errors and increase the accuracy of results. NDVI, NDBI and LST were produced after making band corrections.

Based on Remote Sensing and GIS the study area public parks were GPS data were collected and the boundaries for each park were digitized and a spatial database and maps were produced. This spatial data helps to locate and identify the parks for future management and development.

With respect to Normalized Difference Vegetation Index, the value indicates the greenness of an area, and in the study area, Entoto Mountain, Urban Green areas and river banks were received positive value. The area without vegetation cover was gained lower value. In addition to this, the positive and close to 1 the NDVI value, the higher the evapotranspiration and the lower the temperature. Vice versa is also true.

In the study, NDBI was used as an indication for the Land Surface Temperature. The higher the built-up index, the positive the built-up area to get the higher the surface temperature. Those areas dominated by built-up were clearly identified in the result. The drawback with this technique was, the bare land areas having the same reflectance with that of built-up area, the value get confused. But, the NDBI value in the analysis of Land Surface Temperature, it gives an additive value. On the other hand, to analyze the urban expansion, it supports to have a general overview of a given area.

With regard to LST study, not much is conducted in Ethiopia. These days a tendency of executing a research towards analyzing the LST and UHI in urban built-up environment has got an interest. Despite the effect of climate change, the dramatic expansion of urban areas leads to the micro-climate change and supported with surface temperature increase. Hence, Addis Ababa is a Metropolitan city in Ethiopia; issues of LST and UHI are very sensitive due to the expansion of the built environment, deterioration of vegetation cover, and small area coverage of the urban green spaces like public parks, which is getting worse these days. Therefore, this study is conducted to identify the efficiency of public parks in coping the effect of LST increase and UHI.

5.2. Recommendations

The study revealed that, the mean surface temperature of Addis Ababa from 1985 to 2015 increased by 3.25⁰C of temperature. This surface temperature increase continue without taking any measures to decrease the warmth condition, Addis Ababa gets un-favorable for living. Therefore, the following points are recommended for overcoming the challenges of UHI effect.

- Despite the urban green areas in general and for this particular study public parks were recorded, there has to be a spatial data for conservation, management and assessing their changes through time.
- One of the results noticed in this study was the land-use/land-cover changes, where the built up area covers large area. Therefore, a proper planning should be implemented to overcome the challenges of land surface temperature increase, with the increase the built-up and impervious surfaces and to consider for green area development.
- Strategies should be designed by administrative bodies to mitigate the urban heat island effect through green technology, such as green roofing, planting trees at household level, in construction sector selection and use of building materials, building micro-parks at community level, developing green areas at condominium sites.
- Conducting further researches on analyzing the UHI effect and the existence of vegetation cover to overcome the consequences of climate change and to minimize the impacts of surface temperature.

References

Addis Ababa City Administration Integrated Land Information Center (AACAILIC) (2012). Existing Land Use Map of Addis Ababa. http://www.ilic.gov.et/index.php/en/land-use. Accessed on 5/16/2016.

Addis Ababa City Administration (AACA). Addis Ababa City profile. (2015) www.addisababacity.gov.et/index.php/en/city-hall/city-profile?format=pdf. Accessed on 5/11/2016.

Amanuel Abate and Mulugeta Lemenih (2014). Detecting And Quantifying Land-Use/Land-Cover Dynamics in Nadda Asendabo Watershed, South Western Ethiopia. International Journal of Environmental Sciences, **3** (1)**:**45–50.

Ashraf, M. (2015). A Study Of Temporal Change In Land Surface Temperature And Urban Heat Island Effect In Patna Municipal Corporation Over A Period Of 25 Years (1989 – 2014) Using Remote Sensing And GIS Technique. International Journal of Remote Sensing and Geoscience (IJRSG, **4**(1):71–77.

Central Statistical Agency (CSA) (2015). Ethiopian Population Projection Data. Unpublished report, Addis Ababa, Ethiopia, 29 pp.

Chander, G., Markham, B.L. and Helder, D.L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment **113**: 893–903.

Cheng X., Wei B, Chen G, Li J. and Song C. (2014). Influence of Park Size and Its Surrounding Urban Landscape Patterns on the Park Cooling Effect. Journal of Urban Planning and Development, **141**(3): A4014002.

Chen, X. L., Zhao, H. M., Li, P. X. and Yin, Z. Y. (2006). Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. Remote Sensing of Environments, **104**: 133–146.

Chiesura, A. (2004). The role of urban parks for the sustainable city. Landscape and Urban Planning, **68** : 129–138.

Effat, H. A., Taha, L. G. and Mansour, K. F. (2014). Change Detection of Land cover and Urban Heat Islands Using Multi-Temporal Landsat Images, Application in Tanta City, Egypt. Open Journal of Remote Sensing and Positioning, **1**(2):1–15.

Earth Science Reference Table (ESRT). Relative Humidity Table: file:///C:/Data/5rs_3_2-3.pdf. Accessed on 5/12/2015.

Earth Science Reference Table (ESRT). Relative Humidity Table: http://www.regentsearth.com/Illustrated%20ESRT/Page%2012%20(DP%20&%20RH)/ESRT%20page%2012%20index.htm Accessed on 5/12/2016.

Escobedo, F. and Dubbeling, M. (2014). Guideline 2: Methodological guidelines for Monitoring of Temperature Effects. Resource Centers on Urban Agriculture and Food Security.

Farooq A. (2012). Landsat ETM+ and MODIS EVI/NDVI Data Products for Climatic Variation and Agricultural Measurements in Cholistan Desert. Global Journal of HUMAN SOCIAL SCIENCE Geography & Environmental GeoSciences, **12**(13): 1-11.

Federal Democratic Republic of Ethiopia Climate Resilient Green Economy (CRGE): Green Economy Strategy. (2011). Climate Resilient Green Economy Strategy Committee, Ethiopia.

Feizizadeh, B. and Blaschke, T. (2013). Examining Urban Heat Island Relations to Land Use and Air Pollution: Multiple Endmember Spectral Mixture Analysis for Thermal Remote Sensing. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, **6**(3). DOI: 10.1109/JSTARS.2013.2263425.

Gudina Legese, Dons, K. and Meilby, H. (2013). Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landscape and Urban Planning, **123**: 87– 95.

Hassan-Ali, L. and Hooman, B. (2012). GIS Application in Urban Green space Per Capita Evaluation. Case study: City of Tehran. Annals of Biological Research, **3** (5): 2439-2446.

Intergovernmental Panel on Climate Change (IPCC) (2015). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151 pp.

James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste, J., Elmqvist, T., Frithg, M., Gordon, C., Greening, K. L., Handley, J., Haworth, S., Kazmierczak, A.E., Johnstonl, M., Korpela, K., Moretti, M., Niemela, J., Pauleit, S., Roe, M.H., Sadler, J.P., Ward Thompson, C. (2009). Towards an integrated understanding of green space in the European built environment, Urban Forestry & Urban Greening **8**: 65–75.

Jianguo, W. (2014). Urban ecology and sustainability: The state-of-the-science and future directions, Landscape and Urban Planning, **125**: 209-221.

Jiménez-Muñoz, J. C., Cristóbal, J., Sobrino, J. A., Sòria, G., Ninyerola, M. and Pons, X. (2009). Revision of the Single-Channel Algorithm for Land Surface Temperature Retrieval From Landsat Thermal-Infrared Data, Ieee Transactions On Geoscience And Remote Sensing, **47**(1). DOI 10.1109/TGRS.2008.2007125.

Kumilachew Yeshitla (2013). Green Areas and parks in Addis Ababa, Nws Article in Forum for Social Studies, FSS Update. Issue No. 48.

Maitima, J.M, Mugatha, S.M., Reid, R.S., Gachimbi, L.N., Majule, A., Lyaruu, H., Pomery, D., Mathai, S. and Mugisha, S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa. African Journal of Environmental Science and Technology, **3** (10): 310–325.

Md Shahid, L. (2014). Land Surface Temperature Retrieval of Landsat-8 Data Using Split Window Algorithm- A Case Study of Ranchi District. International Journal of Engineering Development and Research, **2** (4): 3840-3849.

Melissa, K. (2010). The Green Area Ratio: urban site sustainability metric. Journal of Environmental Planning and Management, **54** (7): 937–958.

Meng, F. and Liu, M. (2013). Remote sensing image-based analysis of the patterns of urban heat islands in rapidly urbanizing Jinan, China. International Journal of Remote Sensing, **34** (24): 8838-8853.

Mensah, C.A. (2014). Urban Green Spaces in Africa: Nature and Challenges, International Journal of Ecosystem, **4**(1): 1-11.

Ministry of Environment and Forest (MEF) (2015). Ethiopia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). MEF, Addis Ababa, Ethiopia.

National Aeronautics and Space Administration (NASA). (2016). The Balance of Power in the Earth-Sun System. NASA Facts. www.nasa.gov/pdf/135642main_balance_trifold21.pdf. Accessed on 6/28/2016.

Nina, S. and Ameur, M. M. (2015). Analyzing the Influence of Urban Forms on Surface Urban Heat Islands in Europe. Journal of Urban Planning and Development, **141**(3): A4014003.

Oded, P., Pninit, C. and Arieh, B. (2006). Climatic behavior of various urban parks during hot and humid summer in the Mediterranean city of Tel Aviv, Israel. International Journal of Climatology, **26**: 1695–1711.

Olga, B., Jamie, A. T., Paul, R. A., Richard, G. D., Richard, A. F., Pat, J. and Kevin, J. (2007). who benefits from access to green space? A case study from Sheffield, UK. Landscape and Urban Planning, **83**: 187–195.

Parente, C. (2013). TOA reflectance and NDVI calculation for Landsat 7 ETM+ images of Sicily. Ecology, Forestry and Earth Science, **11**: 351–354

Patrick, M. and Richard, A. (2013). Benefits and Challenges of Urban Green Spaces. Chinese Journal of Population Resources and Environment, **10** (1): 73-79.
Saad S.B. and Nitin K.T. (2104). Built-up area extraction using Landsat-8 OLI imagery. GIScience & Remote Sensing, **51** (4): 445-467.

Pellikka, P. 2008, 'Land use and land cover changes in Africa-from local to continental', paper presented on HERC seminar, University of Helsinki, Helsinki, Aprill 24/2008.

Ramdani, F. and Setiani, P. (2014). Spatio-temporal analysis of urban temperature in Bandung City, Indonesia. Urban Ecosyst, **17**:473–487.

Rajeshwari, A. and Mani, N.D. (2014). Estimation of Land Surface Temperature of Dindigul District Using Landsat 8 Data. International Journal of Research in Engineering and Technology, **3**(5): 2321-7308.

Saad, S .B. and Nitin, K. T. (2014). Built-up area extraction using Landsat 8 OLI imagery. GIScience & Remote Sensing, **51**(4): 445-467.

Siti, N., Afzan, B., Naim, W. M., Alamah, M. (2013). Green Spaces Growth Impact on the Urban Microclimate. Procedia – Social and Behavioral Sciences, **105**: 547-557.

Sobrino, J. A., Rosa, O., Guillem, S., Juan, C. J., Belén, F., Victoria, H., Cristian, M., Yves, J., Juan, C., Mireia, R., Antonio, G. J., Eduardo, D. M., Remo, B. and Marc, P. (2012). Evaluation of the surface urban heat island effect in the city of Madrid by thermal remote sensing. International Journal of Remote Sensing, **34** (9-10): 3177-3192.

Souza, E.M.F.R. (2015). Reflections on Temporal Analysis with Landsat 5 e 8 Images- the use of the NDBI to the evaluation of Urban expansion between 2010 e 2014, in the Marica City, in Rio de Janeiro – Brazil. International Journal of Computer Science and Software Engineering, **4**(6): 156–159.

Stephen, J.V. and Jari, K. N. (2004). Ecology in a multidisciplinary study of urban green space: the URGE project. Boreal Environment Research **9**: 479–489.

The World Bank (2010). Cities and Climate Change: An Urgent Agenda, Urban development Series Knowledge Papers, Washington DC, **10**.

Tony, M. (2012). Heat islands: understanding and mitigating heat in urban areas. Australian Planner, **49** (4): 363-364.

United States Environmental Protection Authority (US EPA) (2008). Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/sites/production/files/2014-06/documents/basics compendium.pdf Accessed on 5/2/2016.

United States Environmental Protection Authority (US EPA) (2008). Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/heat-islands/heat-island-compendium. Accessed on 5/2/2016.

Varshney, A. (2013). Improved NDBI differencing algorithm for built-up regions change detection from remote-sensing data: an automated approach, Remote Sensing Letters, **4** (5): 504-512.

Voogt, J. (2000). How researchers measure Urban Heat Island. AMS Glossary of Meteorology, 2nd Edition, Canada.

Walsh, C. L., Dawson. R. J., Hall, J. W., Barr, S. L., Batty, M., Bristow, A. L., Carney, S., Dagoumas, A. S., Ford, A. C., Harpham, C., Tight, M. R., Watters, H. and Zanni, A. M. (2011). Assessment of climate change mitigation and adaptation in cities. Urban Design and Planning, **164** (2): 75–84

Wan, Z. and Dozier, J. (1996). A Generalized Split- Window Algorithm for Retrieving Land-Surface Temperature from Space. IEEE Transactions on Geoscience and Remote Sensing, **34**(4): 892–905.

Weng, Q., Lu, D. and Schubring, J. (2004). Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. Remote Sensing of Environment **89:** 467 – 483.

World Meteorological Organization (WMO). World Weather Information Service. http://worldweather.wmo.int/en/city.html?cityId=162 Accessed on 5/11/2016.

Wikipedia, the free encyclopedia (2016). Gography of Addis Ababa. https://en.wikipedia.org/wiki/Addis_Ababa#Geography Accessed on 5/16/2016.

Xiaoyun, C., Bensheng, W., Guojian, C., Junxiang, L. and Conghe, S. (2015). Influence of park size and its surrounding urban landscape patterns on the park cooling effect. Journal of Urban Planning and Development, **141** (3): A4014002.

Xu, H. (2007). Extraction of Urban Built-up Land Features from Landsat Imagery Using a thematic oriented Index Combination Technique. Photogrammetric Engineering & Remote Sensing, **73 (**12): 1381–1391.

Zha y., Gao J. and Ni S. (2010). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. International Journal of Remote Sensing, **24** (3): 583–594.

Zhou, Y., Yang, G., Wang, S., Wang, L., Wang, F., Liu, X. (2014). A new index for mapping built-up and bare land areas from Landsat-8 OLI data. Remote Sensing Letters, **5**(10): 862-871.

Zhou, Y., Shi, T., Hu, Y., Gao, C., Liu, M., Fu, S. and Wang, S. (2011). Urban green space planning based on computational fluid dynamics model and landscape ecology principle: A case study of Liaoyang City, Northeast China. Chinese Geographical Science, **21** (4):465–475.

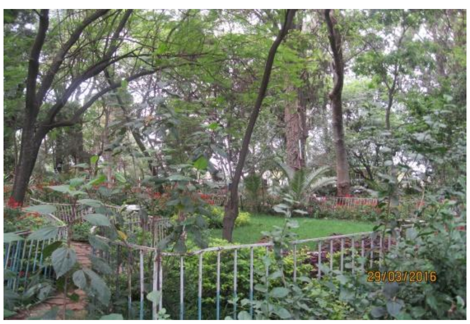
Appendix 1: Sampled public parks photographs

Africa Park

Ambassador park

Bihere Tsige park

Gedame Eyesus park



Gola Park

Kolfe park

Sheger park

Yeka park

Appendix 2: Field Temperature Measurement

Whyrling Psychrometer

Taking field measurement

Appendix 3 : Public Parks in the study area

No	Name of Park	Sub City	Area (m^2)	Area (%)
1.	Gedame Yesus	Addis Ketema	4,128	0.44
2.	Ambassador	Arada	9,393	1.01
3.	Sheger	Gulele	70,000	7.52
4.	Africa	Kirkos	45,707	4.91
5.	Kolfe	Kolfe Keraniyo	20,000	2.15
6.	Gola	Lideta	9,625	1.03
7.	Bihere Tsige	Nefas Silk Lafto	142,726	15.33
8.	Yeka	Yeka	22,081	2.37
9.	Millennium	Akaki Kality	4,284	0.46
10.	Akaki Kality	Akaki Kality	62,518	6.71
11.	Lion Zoo	Arada	12,000	1.29
12.	Peacock	Bole	364,014	39.1
13.	Hamle 19	Gulele	67,968	7.3
14.	Afincho-ber	Gulele	30,209	3.25
15.	Ethio-Cuba Friendship	Lideta	27,226	2.92
16.	Tekle Haimanot	Lideta	3,634	0.39
17.	Lideta 1	Lideta	12,192	1.31
18.	Ferensay	Yeka	22,081	2.37
19	Kaleb	Yeka	1,300	0.14
		Total Area	**931,086**	**100**

Appendix 4: Measured temperature from selected parks

ID	Park Name	Distance from the park (m): Park Center			30			60			90			120			150		
		Max T°C	Min. T°C	Av T°C	Max. T°C	Min T°C	Av T°C	Max. T°C	Min. T°C	Av T°C	Max. T°C	Min. T°C	Av T°C	Max .T°C	Min T°C	Av T°C	Max. T°C	Min. T°C	Av T°C
1	Ambassador	24	16.5	20.25	26.5	16	21.25	27.5	16.5	22	28.5	16.5	22.5	29	17	23	29.5	17	23.25
2	Africa	26	15	20.5	27.5	15.5	21.5	28	15.5	21.75	28	15.5	21.75	28.5	17	22.75	29.5	16.5	23
3	Bihere Tsige	23.5	16.5	20	23.5	17	20.25	24.5	17.5	21	23.5	17.5	20.5	26	18.5	22.25	26.5	17	21.75
4	Gedame Eyesus	25	16	20.5	26	16	21	26	16	21	Settlement hinders the measurement								
5	Gola	25.5	15.5	20.5	28.5	17	22.75	29.5	19	24.25	30.5	18.5	24.5	30	17	23.5	30	17.5	23.75
6	Kolfe	23.5	14	18.75	28	16.5	22.25	28	16.5	22.25	28	16.5	22.25	27.5	17	22.25	26	15	20.5
7	Sheger	22.5	14.5	18.5	26	15.5	20.75	26	16	21	25.5	16	20.75	27.5	16.5	22	27	16	21.5
8	Yeka	26.5	15.5	21	26.5	15	20.75	27.5	15	21.25	27	14.5	20.75	Settlement hinders the measurement					

Appendix 6: Structured Questionnaire for those who visited the park

Addis Ababa University
School of Earth Science
Remote Sensing and Geographic Information System

This questionnaire is designed for collecting public parks related data's for the research study conducted on "Assessing the impacts of Urban Green Areas on Mitigating Urban Heat Island Effect in Addis Ababa. Therefore your honest response with regard to the questions on the paper is very much important to the accomplishment of the paper. Thank you for your cooperation.

N.B: Apply one of the following ways when you give the answer. ☐X Or ☐✓

Age ---------- Sex----------- Education------------------

1. How much time you visit this park?

   A. Always ☐ B. Weakness ☐ C. Holidays ☐ D. Once in a weak ☐

   E. Once in a month ☐ F. If others --

2. What benefits do you expect to gain while you visit this park?

   A. For enjoyments ☐ B. To feel rested ☐ C. For reading ☐

   D. If other ---

3. Do you recognize the difference between being inside and outside the park ?

   A. Yes ☐ B. No ☐

4. If your answer is 'Yes' How do you explain the difference?

   Within the Park: A. Fresh air ☐ B. Refresh our mind (soul) ☐ C. windy air ☐

   D. If other---

   Outside the Park: A. Air is warm ☐ B. Polluted air ☐ C. Affects health ☐

   D. If other---

5. What are the importance of public parks to the society and city?

   A. Protects air pollution ☐ B. Decreases atmospheric temperature ☐ C. Moderates atmospher☐ather D. Beauti☐ city E. If other----------

   ----

   ----

6. Do you know public parks in the city?

   A .Yes ☐ B. Few of them only ☐ C. I don't know other than this ☐

7. Do you think the existed parks are enough?

   A. Yes ☐ B. No ☐

8. If your answer is 'No' what measure should you think to be undertaken?

   A. Expanding and redeveloping the existed one ☐ B. Building new public parks ☐

   C. If other——————————————————————————————

9. If you have any additional ideas——

   ——

   ——