Impact of Urbanization-induced Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort: The case of Dire Dawa, Ethiopia.

Ermias Belete Bekele

A Thesis Submitted to the Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in a Partial Fulfilment of the Requirement for the Degree of Master's in Geo-Informatics Engineering

Office of Post Graduate Studies

Adama Science and Technology University

July, 2023

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APPROVAL SHEET

I, the advisor of the thesis entitled **"Impact of Urbanization-induced Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort: The case of Dire Dawa, Ethiopia."** by Ermias Belete Bekele, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Ermias Belete Bekele have read and evaluated the thesis entitled **"Impact of Urbanization-induced Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort: The case of Dire Dawa, Ethiopia."** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics Engineering.

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

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DECLARATION

I declare that this Master Thesis proposal entitled **"Impact of Urbanization-induced Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort: The case of Dire Dawa, Ethiopia."** is my own work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials utilized in this thesis have been duly recognized and appropriately cited.

Ermias Belete Bekele	__________________	July, 2023
Name of the student	**Signature**	**Date**

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled **"Impact of Urbanization-induced Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort: The case of Dire Dawa, Ethiopia."** prepared under my guidance by Ermias Belete Bekele submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dejene Tesema (Ph.D)	__________________	July, 2023
Major Advisor	**Signature**	**Date**

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LIST OF ACRONYMS AND ABBREVIATIONS

CRGE	Climate-Resilient Green Economy Strategy
CSA	Central Stasistics Agency
DNs	Digital Numbers
EEI	Ecological Evaluation Index
ERDAS	Earth Resource Data Analysis System
ESA	Europpean Space Agency
ESRI	Environmental Systems Research Institute
LST	Land Surface Temperature
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
MLC	Maximum Likelihood Classification
MNDWI	Mean Normalized Difference Water Index
MSS	Multi Spectral Scanner
NDBaI	Normalized Difference Barren Index
NDBI	Normalized Difference Built-up Iindex
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra Red
NMI	National Meteorology Institute

OECD	Organisation for Economic Co-operation and Development
OLI	Operational Land Imager
PM	Prime Minister
SUHI	Surface Urban Heat Intensity
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
UN	United Nations
USGS	United States Geological Survey
UTFVI	Urban Thermal Field Variance Index
VCC	Vegetation Cover Change
WBG	World Bank Group
WPR	World Population Review

ABSTRACT

Urbanization-induced land use and land cover changes have significant impacts on land surface temperature and thermal comfort. This study was focused on assessing an Implications of Urbanization-Induced Land Use Land Cover Changes on Land Surface Temperature and Thermal Comfort in Dire Dawa City between 2000 and 2022. The City is experiencing rapid urbanization, and limitation of green area aesthetical values that has resulted in remarkable surface temperature. Despite this, as of yet, no evaluations have been duly executed pertaining to the thermal or ecological factors in Dire Dawa. The study utilized Landsat and MODIS 11A2 images for the study area. Respectively to analyze and show results clearly, ArcGIS 10.8, ERDAS IMAGINE 2014, and Excel 2013 softwares were used. The LULC pattern was processed by supervised classification with the maximum likelihood classification algorithm and four major land use land cover (Built-up area, Barren land, Shrub land, and sparse vegetation) were identified. The researcher employed NDVI to portray vegetation coverage, the spatial distribution of LST of the study area was extracted and quantified using Landsat thermal bands, to investigate the relationships between different LULC classes and LST, NDBI and NDVI land cover indices have developed and investigated through the use of correlation and linear regression techniques. Furthermore to better assess and evaluate the ecological thermal condition of the city, UTFVI was quantitatively analyzed following an equation. The findings of the study Over the 22-year period revealed that, barren land and shrub land showed continuous decrement, whereas the built-up area expanded significantly, gaining about 10 km^2 land from bare land and shrub land cover categories. The LST has mostly increased in the land classes of bare land, shrub land, and built-up land class. The study reached that LST and built-up area have positive relationship, while have a negative correlation with vegetation. The trends of thermal comfort in Dire dawa shows that the area under the excellent category is continuing to remain constant, while the worst ecological zones have expanded significantly.The study shows that changes in land use and cover affect urban ecology and health. To address these concerns, it is crucial to implement effective measures for sustainable land management practices.

Keywords: *Ecological Evaluation Index; Land Surface Temperature; Thermal Comfort; Urbanization*

CHAPTER I: INTRODUCTION

Urbanization-induced land use and land cover changes have emerged as a pressing concern in today's rapidly urbanizing world. As cities continue to expand, the transformation of natural land into built-up areas has profound implications for the land surface temperature and thermal comfort experienced by urban residents. The alteration of land surfaces through urban infrastructure, increased impervious surfaces, and changes in vegetation cover can significantly impact the urban microclimate, leading to elevated temperatures and reduced thermal comfort. Understanding the implications of these changes is crucial for urban planning, environmental sustainability, and the well-being of urban populations. This study explores the complex relationship between urbanization-induced land use and land cover changes, land surface temperature, and thermal comfort, shedding light on the challenges and opportunities associated with urban development in a changing climate.

1.1. Background of the Study

Land use and land cover change has indeed been a significant global concern. Over time, various human activities such as urbanization, deforestation, agriculture expansion, and industrialization have significantly impacted land use and land cover patterns globally. These activities have led to the conversion of natural areas such as forests, grasslands, and wetlands into urban and agricultural areas. Consequently, this has resulted in a decrease in natural habitats and biodiversity, loss of carbon sinks, increased greenhouse gas emissions, and altered ecosystem services. Consequently, the focal point of interest pertains to the levels of carbon dioxide is increasing in the atmosphere which in turn detecting the surface energy budget there by producing changes in local, regional and global climate (Lilly, 2009). Uncontrolled population growth and the rapid development of world-wide urbanization have an extreme impact on the environment (Coskun, 2008).

Urbanization-based surface improvements are mainly caused by the clearance of vegetation area, which can adversely affect the climate of the surface globally. Throughout the course of human civilization, the Earth's landscape has undergone significant transformations as a result of human activity. This has been driven by the constant pursuit and acquisition of vital resources. In the recent decade, climate scientists have paid increased attention to local and regional climate under anthropogenic impacts to better understand how the climate's driving elements are changing (Adegoke et al., 2003). The fastest development of socio-economic processes is the dominant of the key causes of global climate change. At present, it is observed that over fifty percent of the global populace predominantly inhabits in urban areas, and that number is expected to reach 66% in the year 2050 (United Nations, 2014), in which Africa is projected to have the fastest urban growth rate (Organization for Economic Co-operation and Development , 2020). In the years 2020–2025, urban population growth in Africa is continuously increasing at a rate of 3% per year, which is six times the rate projected in industrial countries (Hope, 2017). Despite of being below the Sub-Saharan African average of 37%, the Ethiopian urban population is dramatically changing and is predicted to be 30% of the people in urban areas, and the urbanization rate will be 3.8% per year (World Bank Group, 2015).

The issue of thermal comfort globally refers to the challenge of ensuring comfortable indoor temperatures in different geographical locations and climates worldwide. The challenges of thermal comfort vary across regions. Achieving optimal thermal comfort is important for human well-being, productivity, and overall quality of life.

Land use land cover change (LULCC) analysis is the best way to measure and monitor available pressures on terrestrial ecosystems and biodiversity (OECD, 2018). Monitoring land use and land cover change on a global scale involves satellite remote sensing, geospatial analysis, and data assimilation techniques. These methods provide valuable information for policymakers and researchers to understand the extent, patterns, and drivers of these changes.

This research was aimed to determine the LULC dynamics of Dire Dawa city and to show the correlation with the city's climate condition to resolve planning inconsistencies and environmental management decision-making gaps. It is particularly focused on an implication of LULCC on the LST and thermal comfort variance of the city. This was done using data collected by remote sensing technologies. The researcher contends that it is necessary to determine the current state of LULC patterns, responses and patterns of surface temperature to each LULC type, and thermal comfort variance in Dire Dawa city to provide recent and updated information for urban planners, environmental and climate managers, and to design inclusive planning. This could potentially play a substantial and noteworthy role within the domain of managing natural resources and fostering sustainable development.

1.2. Statement of the Problem

The biggest urban problem facing cities around the world today is the result of land use change induced by urbanization. Future increases in climate change and urbanization will exacerbate urban heat islands, especially during heatwaves. Global warming is becoming an ever-more pressing issue and its effects are being felt everywhere, in Dire Dawa city. Excessive heat can of course affect people's health. If exposed for long periods to uncontrolled heat, it can be fatal especially if a person has diabetes or heart disease. These problems are posing a health and sanitation threat to the city. Aware of the growing problem, the city's administration health office has issued a warning that people should take extra care during the hottest part of the day (Addis zeybe, 2022). The city government is planning to address some of these issues, through five environment related projects. Prior research in Dire Dawa has focused on revealing LULCC trends and/or effects, its Drivers and influence, the significant effects on surface runoff management for environmental flood hazard mitigation (Milkias and Toru, 2018; Erena and Worku, 2019), rather than the overall LULCC and LST trends and associated impacts on the respected sectors. In spite of the magnitude of the implication of LULCC on the environment and human health, there is limited mitigation measure on the issue in Dire Dawa City. Due to the extent to which climate change is not well examined to date, this study seeks to address this gap in the literature by examining implication of LULCC on LST and urban thermal comfort level. The focus of research in the field of urban LST is still limited, and there is a need for more comprehensive studies to adequately understand and address this emerging concept. Furthermore, none of the academies examined the city's thermal ecology variance, which is the currently developed index technique or statistic for evaluating urban environments from an ecological point of view. This particularly leaves a wider research gap when it comes to the impacts of urbanization-induced LULCC related to LST with respect to the urban thermal comfort ecology of Dire Dawa city. Hence, a study of the effects of urban LULCC on LST and variations in urban ecology, notably in Dire Dawa city, becomes necessary, pertinent, and timely. The findings of this study would applied to inclusive development, sustainable urban planning, appropriate policy intervention, the development of SUHI mitigation techniques, and sustaining urban thermal comfort in Dire Dawa and cities with comparable geographic characteristics. The methodology can also serve as a foundation for other research conducted in other cities.

1.3. Objectives

1.3.1. General Objective

The General Objective of this Study is to assess the Impacts of Land Use Land Cover Change on Land Surface Temperature and Thermal Comfort in Dire Dawa City.

1.3.2. Specific Objectives

To conduct the general objectives the following specific objectives were formulated to:

- Analyze changes in Land Use Land Cover in the study area from 2000 to 2022.
- Assess spatiotemporal variations of LST in the study area from 2000 to 2022.
- Ascertain the relationship of LST with the patterns of vegetation and built-up land cover dynamics in the study area over the study period.
- Assess the thermal comfort level of Dire Dawa City over the study period.

1.4. Research Questions

With the above objectives the study set to analyze and answer the following scientific questions:

- How was LULC in Dire Dawa city changed over the study period?
- What is the Variation of LST to each LULC types of Dire Dawa City during the study period?
- How was LST in study area correlated with NDVI and NDBI in the study period?
- What is the thermal comfort level of urban ecological variance in Dire Dawa City over the study period?

1.5. Significance of the Study

By mapping and predicting the continuous dynamic of LULCC and climatic variability spatially and quantitatively using remote sensing data, the study will contribute to the work of decisions made by urban planners, civil society, climate managers, and other governmental and non- governmental organizations on sustainability and environmental change management-related concerns.

This would help to address the current gap in research in this thematic area and provide academic value to individuals and organizations working in such environments. Furthermore, the findings of the study would provide updated information to manage microclimate status and decide properly on the utilization of resources and implementation of land use policy. Moreover, it would foster and improve the efficiency and effectiveness of the work of urban planners and land administrators. For the city administrative this study would use as a basement to monitor the scale of urbanization processes to adapt space management procedures to the changing environment.

Finally, it would provide insight for future researchers who were interested to investigate the impact of LULCC on LST, specifically on UTFVI, for measuring urban health and ensuring sustainable development.

1.6. Delimitation Scope

Spatially, the scope of the study was confined to Dire Dawa City. The city is characterized by high spatial urban expansion, rapid population and economic growth, rapid infrastructure development, and high industrial activity.

Thematically, this study was focused on urban LULCC and climate variability. Despite the concept of LULC and climate, by their nature, being too broad, the study will highly delimited to the impact of LULCC on LST and urban thermal comfort patterns.

Temporally, the scope of the study was limited to periods from 2000 – 2022 that is using remotely sensed data as reasonedout under methods part. Methodologically, using both primarily and secodary data perfom LULC classification via the algorithm of MLC Quantitatively and calculate Urban thermal comfort level using UTFVI variance.

1.7. Limitations of the study

This research, like other academic researcher faced major challenges that exert limitations on the overall process of the study. The study was limited by the lack of high-resolution remote sensing data for analyzing vegetation cover in the study area. Thus, such limitations were filled by using or cross-checking with different remote (Google earth) data and field observation on selected sites. Furthermore, the study also experienced finance limitation, this was corrected using existing budgets.

There are some downsides in the resolution difference between satellite images, especially in the thermal band. For example, the resolution of Landsat 5's thermal band (band 6) is 60m, whereas the resolutions of Landsat 9 (band 10) and MODIS thermal band (band 10) are 120m and 1km, respectively. The researcher used the resampling method at 30 m resolution to resolve such differences.

1.8. Operational Definitions

Urbanization: despite most of them arguing it is a process of change. Traditionally urbanization was defined as the process of population concentration (Tisdale, 1942), while urbanization is not the only concentration of population contemporarily it was defined as the change in activities from agrarian to service and industrial (Chaolin, 2020). It is also the process of making an area more urban (oxford dictionary). According to United Nation ((UN), 2014), it is the method of urbanizing the rural area due to economic and industrial development.

Population Growth: population agglomeration, which has significant implications for environmental sustainability. In addition to the normal urban demographic expansion, urbanization maybe a consequence of rural population migration (Avis, 2016).

Urban Size Expansion: expansion of Urban borders and urban centers that have developed (mostly through reclassification of villages as they have been growing or developing to meet national urban criteria).This implies the city's built-up area expansion is characterized by horizontal growth, by changing the natural use of the land and leaving the peri-urban environment and livelihoods at risk.

Land cover: refers to the biophysical cover of the earth's or land's surface, such as forest, shrub/bushland, and grassland, as well as water. The land cover also refers to the characteristics of the earth's land surface that are covered by flora, desert, water bodies such as lakes, seas, and oceans, as well as bare soil and ice.

Land-use: is defined by the activities, arrangements, and inputs that humans make to produce, develop, adapt, or sustain a specific land cover type (Gregorio, 2005). Land use also refers to how humans use the land for various reasons, such as settlement, industrial zones, agriculture, and grazing.

Land-use and land-cover change: defined as any biophysical change in land-cover, such as vegetation cover and waterbodies, as well as improper land usages for various activities, such as grazing, cropping, and irrigation (Quentin et al., 2006). Conversion and modification are two different types of land-use and land-cover changes.

The Land Surface Temperature (LST): is the radiative skin temperature of the land surface, as measured in the direction of a remote sensor (Copernicus, 2021). It is estimated from Top-of- Atmosphere brightness temperatures from a constellation of geostationary satellites. Its estimation further depends on the albedo, vegetation cover, and soil moisture.

Urban development planning: The design, development and regulation of the uses of space that focus on the physical form, economic functions, and social impacts of the urban environment.

1.9. Organization of the study

The full paper of this conducted study consists of five chapters. The first chapter of the paper contains introductory concepts such as background of the study, statement of the problem, research questions, objective, scope and limitation of the study. Chapter two presents review of related bodies of literatures and various studies conducted by scholars and researchers on the same topic. It also presents review of concepts that are central to this study and the theoretical foundations of the research. The third chapter covers the methodological aspects of the research that were used by the conductor to realize the study including the collection and analysis of data. The fourth chapter presents the data collected through different data collection tools, analysis, interpretation and discussion of data and the major findings of the study. The last section presents conclusion and recommendation of the study as well as suggestions for future studies. At the end, list of references and appendices were attached.

CHAPTER II: LITERATURE REVIEW

2.1. Theoretical Framework

Rapid urbanization has become a defining characteristic of the 21st century, leading to profound changes in land use and land cover patterns across the globe. As urban areas expand, natural landscapes are transformed, resulting in altered land surface temperature and subsequent impacts on thermal comfort. Understanding and quantifying the implications of urbanization-induced land use and land cover changes on land surface temperature and thermal comfort is crucial for sustainable urban planning and design.

2.1.1. Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is a widely used remote sensing index that measures the presence and health of vegetation in an area. It is based on the principle that healthy vegetation absorbs most of the visible light and reflects a large amount of near-infrared (NIR) light. NDVI combines the reflectance values from these two wavelengths to calculate a numerical index that indicates the vegetation abundance and vigor. The NDVI formula is simple: (NIR - Red) / (NIR + Red), where NIR represents the near-infrared reflectance and Red represents the red reflectance. The resulting NDVI values range from -1 to +1, with higher values indicating a greater amount of vegetation. Negative values signify non-vegetated surfaces such as water or bare soil, while positive values correspond to different levels of vegetation coverage. One of the major applications of NDVI is in monitoring and assessing vegetation conditions over large areas. Its ability to quantify vegetation abundance and dynamics makes it valuable for various ecological and agricultural studies. For instance, NDVI has been used to monitor vegetation health and productivity, estimate crop yields, assess drought and stress conditions, analyze land-use and land-cover changes, and map forest cover. The use of NDVI is not limited to satellite imagery alone. This versatility allows researchers and land managers to obtain NDVI data at different spatial and temporal scales, depending on their specific needs. Various studies have demonstrated the effectiveness of NDVI in assessing and monitoring vegetation. For example, a study by Tucker et al. (1985) showed a strong correlation between NDVI and the photosynthetic capacity of plant canopies. Another study by Pettorelli et al.

(2005) highlighted the ability of NDVI to detect changes in vegetation phenology and track shifts in ecosystems.

2.1.2. Land Surface Temperature

According to the European Space Agency (ESA) (2021), how hot the Earth's surface feels to the touch in a specific spot is the simplest definition of LST. The surface for a satellite is whatever it sees when looking down through the atmosphere to the ground. The LST is not the same with the air temperature reported in the daily weather report. LST is a measurement of thermal radiation emitted from the land surface when incoming solar energy interacts with and heats the ground or the canopy surface in vegetated areas (Khan et al., 2021).

The surface temperature was retrieved using the thermal band(s) of Landsat imageries. To calculate the land surface temperature, radiometrically corrected thermal infrared bands of Landsat images basically Landsat TM and ETM+ band 6 (thermal in- frared band) and Landsat 9 band 10 and 11 (thermal infrared bands) were used to estimate terrestrial surface temperatures by converting Digital Numbers (DNs) into radiance.

2.1.3. Urban Thermal Comfort

The Urban Thermal Comfort Index (UTCI) is a widely used method to evaluate and quantify thermal comfort in urban areas. It takes into account various meteorological parameters such as air temperature, humidity, wind speed, and radiation, as well as personal activity levels and clothing insulation. The UTCI provides a standardized and objective measure of thermal comfort, contributing to the planning and design of urban spaces that prioritize the well-being of individuals. Several studies have focused on the development and application of the UTCI. One notable reference is the work by Błażejczyk et al. (2010), who proposed the UTCI as an alternative to existing thermal indices. Their research involved extensive physiological measurements and subjective assessments, resulting in a comprehensive and internationally applicable index. The UTCI has also been utilized in urban planning research. For instance, in a study conducted by Thorsson et al. (2014), the authors analyzed the impact of climate change on future thermal comfort conditions in European cities using the UTCI. To better assess and evaluate the ecological thermal condition of the city, UTFVI is quantitatively analyzed following an equation used by many researchers (Guha et al., 2017; Naim and Kafy, 2021;

Zhang et al., 2006). The values of UTFVI were segregated into six distinct groupings in accordance with six distinctive ecological assessment indices.

2.1.4. Normalized Difference Built-Up Index

The normalized difference built-up index (NDBI) is a spectral index commonly used in remote sensing to detect and quantify the extent of built-up areas in urban environments. It is based on the analysis of different reflectance properties of various land cover types, with specific emphasis on distinguishing built-up areas from non-built-up areas. The NDBI calculation involves the differencing of near-infrared (NIR) and shortwave infrared (SWIR) reflectance bands, followed by normalization to account for variations in atmospheric and sensor conditions. One of the earliest mentions of the NDBI can be found in the research paper titled "A Built-up Index for Rapid Mapping of Urban Areas Using Landsat TM and ETM+" by Zha et al. (2003). The authors introduced the NDBI as an effective tool for extracting and analyzing urban areas from multi-temporal Landsat satellite imagery. They demonstrated the usefulness of NDBI in urban growth monitoring, land-use planning, and environmental assessment. Since then, the NDBI has been widely adopted and further studied in numerous research articles and applications worldwide. For example, the paper "A Modified Normalized Difference Built-Up Index for Mapping Urban Built-Up Areas Using Landsat Data" by Chernetskyy et al. (2015) proposed a modified version of NDBI to enhance its sensitivity to built-up areas and improve its mapping accuracy.

2.1.5. Land Use Land Cover classification theory

Land use and land cover classification refers to the process of categorizing and mapping different types of land use and land cover classes within a specific geographic area. This classification is fundamental for various applications including urban planning, environmental management, agriculture, and natural resource monitoring. The theory behind land use and land cover classification involves the analysis of remotely sensed data, such as satellite imagery, and the application of classification algorithms to differentiate and label various land cover types. One widely used theory for land use and land cover classification is the Maximum Likelihood Classification (MLC) approach. MLC is a statistical method that assigns each pixel in an image to a specific land cover class based on the maximum likelihood criterion. This approach assumes that the statistical distribution of each land cover class is known and follows a specific probability distribution. The pixel is then assigned to the class with the highest likelihood value, considering the probability distribution parameters for each class (Congalton, 1991).

2.2. Empirical Framework

In this section a very brief review of body of the literature was conducted. A massive amount of books, journals, articles, and publications were presented and discussed. Review of previously conducted researches and finding were made in empirical review. Many researches had been conducted in impact of land use land cover change on land surface Temperature in Ethiopia and all over the world. Different scholars used different Technology options and approaches to evaluate the various land surface temperature variations. A number of studies results had been published, some of the thesis paper is reviewed and evaluated in the subsequent sub focus.

2.2.1. Global perspectives

A lot of research concerning LULCC impact on LST has been carried out in several regions of the world. There are studies focusing on land use land cover change at expense of one class up on another. Kess et al. (2004) has carried out the change in land use and cover at a global scale, particularly they emphasized the cropland and forest areas. They observed the expansion of crop land at the expense of the forest. Prakasam (2010) investigated land use/land cover change in the Kodaikanal taluk of Tamil Nadu over 40 years. Major changes were noticed in this study, such as a rise in the area under built-up land and harvested land, while a decrease in the area under forest and water bodies. Bisht and Kothyari (2001) conducted Land cover change analysis of the Gurur Ganga watershed in Uttaranchal. The study found that the area under agricultural and settlement increased, while the area under forest and barren land decreased.

LULCCs occurred due to natural and anthropogenic factors. In a research conducted in the Shurugwi district of Zimbabwe's Midlands Province, Mark and Kudakwashe (2010) discovered a rise in farmland.

Large sections of forest were cleared for a variety of farm- related operations, including the creation of new farming plots, the harvesting of wood for fuel, and the construction of poles for residences and cattle pens, among other things.

From 2001 to 2010, Javed and Khan (2012) looked at how land use and land cover changed as a result of mining activity. The study found that while dense forest area, cultivated land, and water bodies have all decreased, settlement, wasteland, and uncultivated land have all increased, owing to anthropogenic activity.

The research conducted by Said (2013) performed at changes in LULC in Sulaymaniyah, Iraq and identified differences in LST among different land cover categories. This study showed that, the barren land has the highest record of LST in the study area. Xueqin Li et al. (2021) undertook analyses across multiple cities simultaneously using a common methodology to understand more about the importance of regional climate conditions and patterns of urbanization in determining the extent and distribution of UHI effects. This study compares SUHI between East African cities located in different climatic zones and assess how they vary in space and time.

Furthermore, Dissanayake et al. (2019) was assessed impact of the landscape structure for the deviation of LST in the African region using a geospatial approach. The vegetated urban fraction can regulate the effect of LSTI by providing shade to the land and accelerate higher albedo through evapotranspiration to generate a cool island against the heat island. Matamyo et al. (2019), conducted a comparative analysis to examine the relationship between LST and the spatial patterns, Composition and design of sealed areas and green spaces in four African cities, Lagos, Nairobi, Addis Ababa and Lusaka. OLI/TIRS Landsat data and various geospatial approaches were used to facilitate the analysis, including urban-rural gradient, UHI intensity, statistics and metric-based cityscapes. The results show a significantly strong correlation between mean LST and the impervious surface and green space along the configuration of cities.

Even if there were several differences from study to study regards to put in the results of LULCCs and drivers representation behind of these changes in the findings of these recognized studies, they did imply that Land-use land-cover changes have become major problems for the world, and it is a significant driving agent of global environmental changes by inducing changes in global systems and cycles. In this way, In oppose to urban features which are gloomy and cause temperature rises, Vegetation helps to cool the air in its vicinity by converting solar radiation into humidity during the evaporation process, which lowers the temperature. Besides, they provided important perspective into the integrated result obtained from different source and technology for the fair representation of the spatial distribution of land surface temperature and better understand the inherent thermal properties of surfaces and identify the major factors for the spatial variation of land surface temperature of the area.

2.2.2. Local perspectives

In the context of Ethiopia, the effects of LULC changes have been assessed by several studies in different parts of the country. Regasa et al. (2021) performed the land use land cover changes of Ethiopian basins. They found that the natural aspect of the basins has been changed to agricultural land, water body, commercial farm, and built up or resettlements. These modifications were at the expense of the vegetation land of the basins. Belayneh and Eyasu (2021) in their findings on the study taken on land use land cover change and its driving forces in Shenkolla watershed which is found south central of Ethiopia showed that, there is a decrease in forest land and an increase in agricultural land. Thus, according to the authors agriculture land increased from 70.49 percent in 1973 to 79.48 percent in 2017, while forest land decreased from 29.51 percent in 1973 to 20.52 percent in 2017. Moisa and Gemeda (2021) studied the urban expansion and land use and land cover changes of Addis Ababa from 1990 to 2020 using geospatial techniques. According to their analysis findings, the built-up land increased, and the agriculture and grassland areas decreased under the studied time frame. At this time, due to the expansion of built-up areas, the agricultural and grassland areas were converted to built-up areas from 1990 to 2020, respectively. This shows how serious the explosion of built-up is at the expense of the natural aspects of the city. These reviewed studies by the researcher showed that urban land use land cover change mostly takes place with the change of the builtup at the expense of forest and agricultural lands. This shows how serious the explosion of built-up is at the expense of the natural aspects of the city. Nevertheless, these studies were performed at interval of 10 years or more year time frame interval.

Previously, different researchers in Ethiopia did researches in relation to the impact of LULC changes on land surface temperature. Finally, the results show that negative correlation was found between Normalized difference vegetation index and Surface Temperature. Balew and Korme (2020) carried out study on the impact of LULCC on LST in Bahir Dar Town between 1987 to 2017 showed that the built-up area were increased and the LST of the town also increased during the study period. This implies how the expansion of built-up has a direct impact on the local climate. The NDVI has been the most commonly used index in vegetation dynamics.

Mikias Biazen Molla (2020) was conducted Study in Hawassa City Administration, for estimating the temporal land surface temperature using thermal remote sensing.

It has been seen that there is Increase in built-up area from 2002 to 2019 and physical expansion of area has expanded. This study examined the change in land surface temperature over different land use/land cover of the area over the period of time (17 years) where developmental activities alters the natural ecosystem.

According to mitiku and lachisa (2021) their study attempted to analysis of Spatiotemporal Land Surface Temperature in Relative to Different Indices (NDVI, NDBaI and MNDWI) using Geospatial Techniques in three selected districts Gida Kiremu, Limu and Amuru, western Ethiopia. The study found that the vegetation area (NDVI) and Water bodies (MNDWI) have a strong negative relationship with land surface temperature, whereas Barren land (NDBaI) have positive relationship with land surface temperature. Daniel et al. (und) in their study of the impact of Land Use Land Cover (LULC) changes on Land Surface Temperature in addisababa as study area examined Urban/built-up areas expanded dramatically, while agricultural land and forest declined. The observed changes in the LULC were largely attributed to population pressure on land, rapid infrastructure expansion, and poor land-use planning. Furthermore, the temperature differences between the city/built-up area and the surrounding countryside have increased significantly. The study evaluated UHI spatial patterns and temporal variations in the city of Addis Ababa.

Even if those researchers were used thermal remote sensing data and produce LST map, they missed the statistical analysis part for studies were conducted for dry season and daytime.

Worku et al. (2019) attempted to assess vegetation cover change (VCC) and its impacts on rainfall and land surface temperature (LST) in a highly deforested and populated area of Ethiopia using Landsat images to evaluate rainfall and LST in the area. Therefore, the mean annual rainfall decreased as vegetation cover declined in the central, northern and southeastern parts of North Gondar Zone. On the other hand, mean LST increased as vegetation cover in the area declined, underlining the positive and negative impacts that vegetation cover has on local rainfall and LST, respectively. Haylemariyam (2018) detected Land Surface Temperature in Relation to Land Use Land Cover Change in Dire Dawa City and identified that, the change in land use land cover because of from urban growth, the expansion of settlements and the construction of new built or residential units in the city leads to an increase in the temperature at the surface of the ground.

In particular, the UHI effect exposes urban inhabitants to additional heat stress, generating extra thermal discomfort in many cities under particular urban development patterns and geographic conditions, and increasing heat-related health risks. Yet, urban thermal comfort environment from the perspective of ecology of any location would be analyzed.

Sisay and korme (2019) examined the spatial variation of surface temperature in the study area located within the rift zones, using an algorithm that was prepared by taking the Normalized Difference Vegetation Index threshold method. The spatial variation of LST (Land Surface Temperature) in the city is the result of different major factors. Mulualem Asfaw (2017) analyzed the dynamics of LULC change (1999-2014) and its impact on LST. This research was undertaken to analyze the potential of multispectral satellite data to retrieve or estimating land surface temperature over Debra Tabor District, from 1999 to 2014. The results have shown that the effect of different land use land cover types on land surface temperatures. The global focus is on Earth's surface temperature, which has a strong correlation with human health and is influenced by the depletion of natural resources. Research suggests that urban areas should prioritize increasing vegetation to support the city's ecosystem and reduce the urban heat island effect.

2.2.3. Research and knowledge gaps

Nevertheless, the above reviewed studies offered a good perspective and could improve considerably the impacts of urban LULCC on LST, they are not quite enough, and It is a major task for urban landscape planners to construct an effective and harmonious urban ecological and maintain a sustainable urban development environment enabling them to meet the principles of conformity, harmony, circulation, safety and diversity.

Even if there has been Study Conducted on the impact of land use land cover change (LULCc) on land surface temperature (LST) in Previous studies, however relied on long-term changes (e.g., decadal or longer). As a result, they provided little insight into the effects of short-term (e.g., 5 years or less) changes in urban areas, which is critical given that the current rapid urbanization. Rapid urbanization encourages the rapid development of structures and pavement, as well as the expansion of barren land during the construction process.

Since almost all studies were conducted for dry season and daytime, it is not provided enough information on behave of remaining season and time. However, temporal analysis is required for in-depth understanding; i.e., night time, wet season etc. Regarding to this multi spectral and multi temporal satellite data have to be extracted for the fair representation of the spatial and Seasonal distribution of land surface temperature and better understand the inherent thermal properties of surfaces and identify the major factors for the spatial variation of surface temperature of the area with in one consistent frame work.

Furthermore, LST studies using thermal remote sensing data is recent , suggests more studies are required to provide increased understanding about the impacts of LULC change on urban heat island at various spatial and temporal scales which is critical for urban sustainability and ecology. Moreover, the retrieval of land surface temperature (LST) from remotely sensed thermal infrared data has become widely recognized as an effective tool for examining spatial patterns of UHIs in relation to urban thermal comfort variance. Yet, the studies focused on SUHIs based on LST retrieval from Landsat data are not more enough saturated.

Despite the fact that the above reviewed studies has been used different indices, the studies attempted the most common NDVI index in vegetation dynamics to analysis of Spatiotemporal Land Surface Temperature in Relative to other Indices (UTFVI, NDVI, NDBaI and MNDWI). All index variables play an important role to estimate LST. The use of different indices provides increased understanding for the spatial variation of surface temperature of the area. In addition to providing an indicator of LST variability, UTFVI is also a major variable in urban thermal comfort. It is important to analyze and increase the understanding of the complex interactions between the environmental variables to figure out which one is the most important one for time frame of study area. To be able to assess urban thermal comfort level conditions with remotely sensed data with high accuracy will improve monitoring and management of mitigation approaches.

Generally as the trend of Dire Dawa city revealed that Land use land cover changes significantly alter the surface energy budgets of urban area. It brings about numerous direct and indirect impacts on urban inhabitants, primarily affecting their health, So Urban environment from the perspective of ecology of any location would be analyzed which has never been studied previously.

The researcher would categorized and decimated the ecological condition of the urban environment in the study area using the Urban Thermal Field Variance Index (UTFVI), which is the currently developed index technique or statistic used for evaluating urban environments from an ecological perspective. Based on the LST estimation, the urban ecology variance analysis of the city is necessary for ecological evaluation and thermal comfort level of urban health.

2.3. Conceptual Framework

Conceptual model demonstrates connection of independent variables to dependent variable. The former is presumed to be the cause of the changes and affects the latter which is the effect. The conceptual framework is further defined as the study of the relevant variables of the research and maps out how they might relate to each other, often represented in a visual format (Swaen, 2021). It helps the researcher to see and visualize the proposed relationship between the variables easily and quickly.

Similarly, the researcher identified the relevant variables of the case study and depicted them using the diagram method. The diagram framework of this research illustrates the association between and/or among the identified variable of the study.

The urbanization trend is reflected in increasing the number of urban residents, either by normal population increase, the annexation of rural regions to urban areas or relocation of people (from other urban or rural areas) and by physically extending urban areas to non-urban areas. People were moving or migrating from rural to urban to get better economic, and social services such as education, health care, sanitation, job and life (Rinkesh, 2021). Contributes to increasing demands of land for economic, social, transport, building, and other infrastructural uses which can affect and become issues of natural land modification and may affect the urban thermal condition.

With the continual modification of the natural setting and/or cover of the land, there is an increase of an urban heatwave. The urban may change from Green Island to urban heat island. Thus, the improvement of surface area through anthropogenic activities leads to the change of surface temperature.

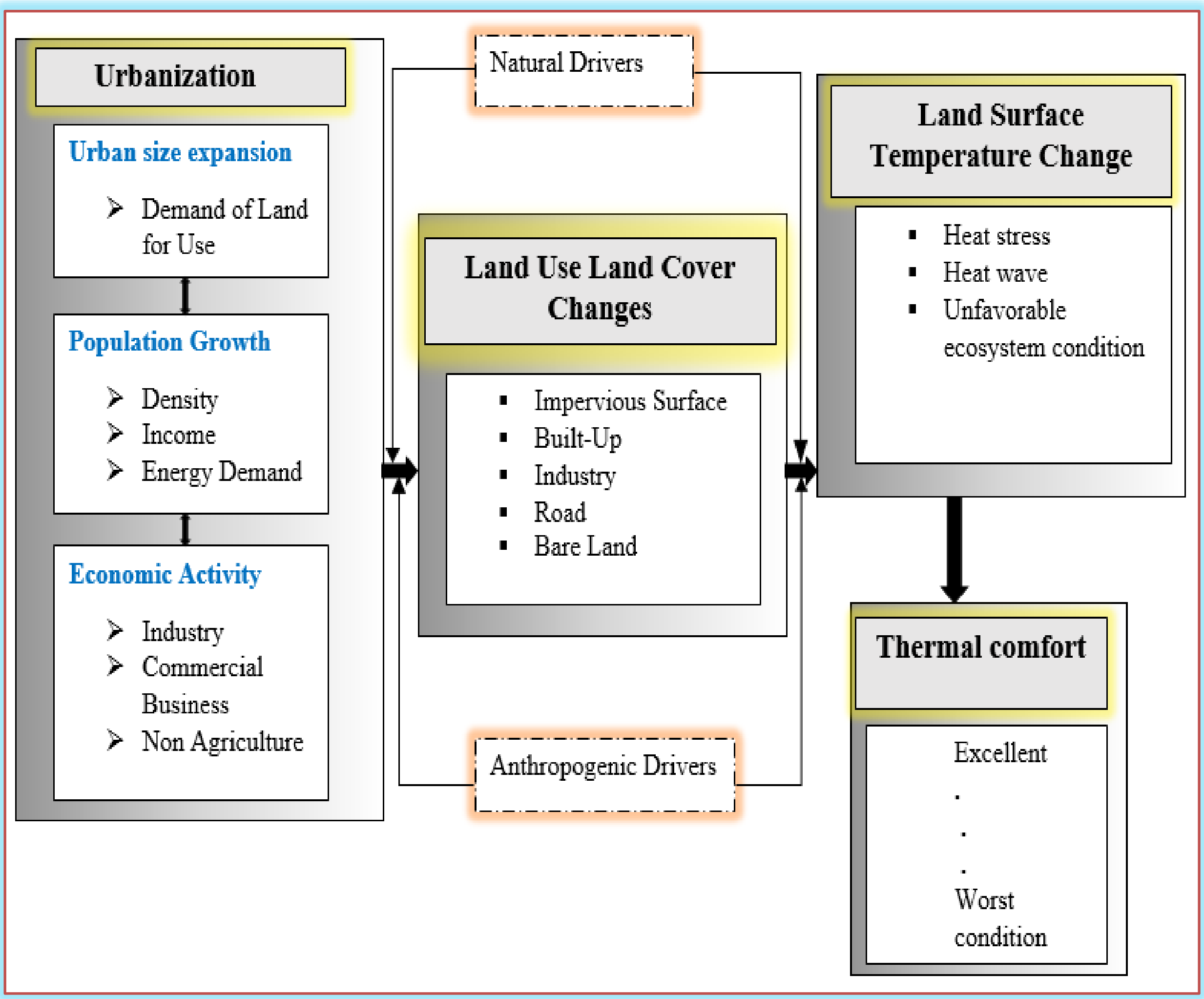


Figure 2.1: Conceptual framework of the study (Sources: Related documents and own articulations (2022)).

CHAPTER III: MATERIALS AND METHODS

This particular chapter offers a comprehensive and detailed overview of the research domain, including an exhaustive analysis of the various types as well as sources of data that were utilized in the study. It also explains the methods and tools employed for data analysis, as well as the relevant mathematical equations including NDVI, radiance, reflectance, land surface emissivity (LSE), LST, and others. These parameters were utilized to evaluate the land use and cover conditions, LST status, and overall thermal stress or comfort levels in Dire Dawa City over a period of 22 years.

3.1. Description of the Study Area

3.1.1. Geographic Location

Geographically, Dire Dawa City is located in Eastern part of the country on the boarder of Awash plain and on the Eastern highland just at foot slope of the Dengego mountain between 9 ° 27' and 9 ° 49'N Latitude and 41 ° 38' and 42 ° 19'E Longitude A region is characterized by a hot and dry climate. Dire Dawa was established in 1902 as a relatively lowland link bypassing the higher, ancient city of Harar on the Djibouti - Addis Ababa railway. Its eastern, low-land position generates a hot climate (Mean 25ºC), occasioned by a seasonal river that floods the river-bank areas. It is 515 kilometers away from the capital. Dire Dawa is known for its strategic location as a major transportation hub connecting Ethiopia with neighboring countries like Djibouti and Somalia. The city serves as an important trade center and gateway to the Red Sea. Tourism in Dire Dawa is gaining significance, thanks to its historical and cultural attractions. Visitors can explore landmarks such as the Dire Dawa Railway Station, Chat Market, Kefira Market, and the historic buildings in the European Quarter. The Harar Jugol, a UNESCO World Heritage Site known for its ancient walled city, is located nearby and is a popular tourist destination.

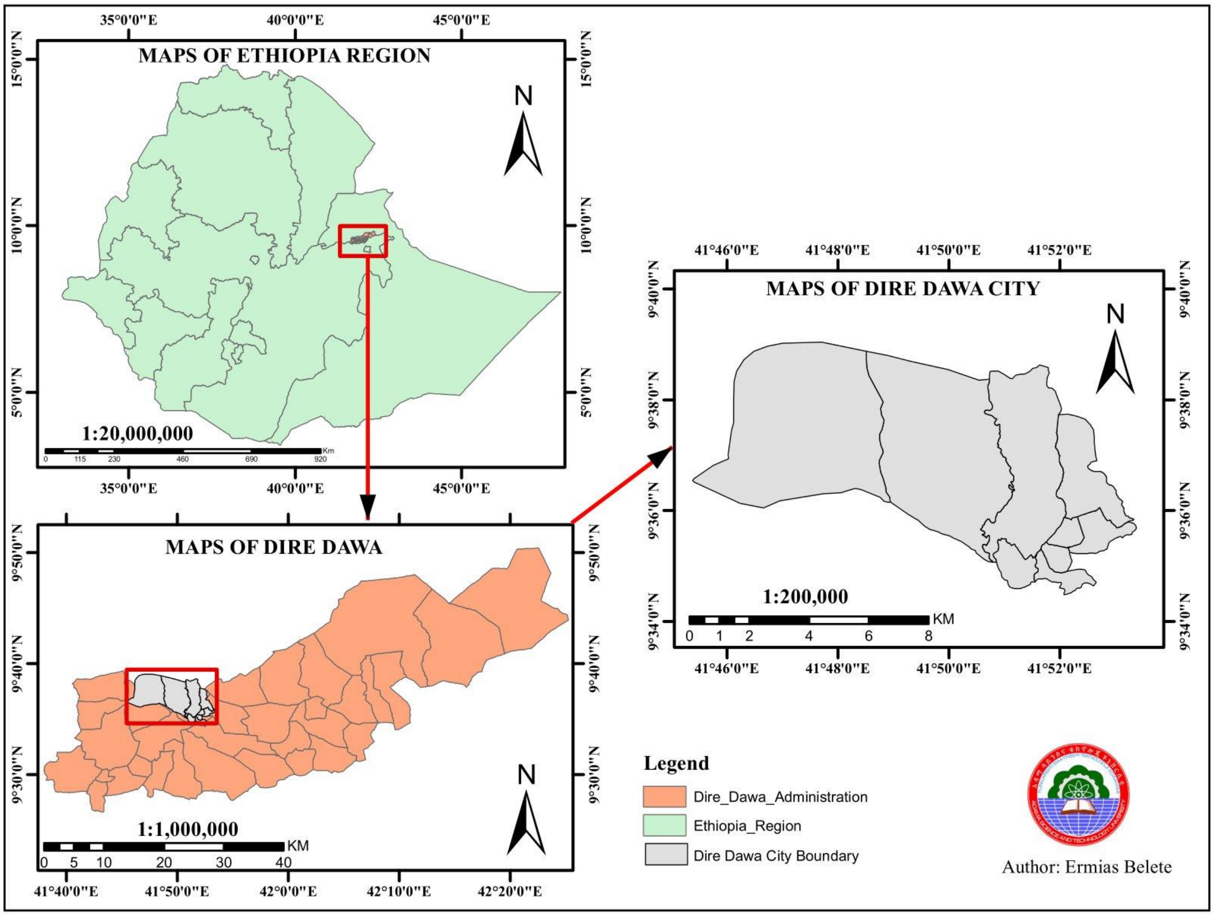


Figure 3.1: Location map of Dire Dawa city. (Source: adapted from researcher techniques, 2022.)

Overall, Dire Dawa City is a vibrant and dynamic urban center that offers a unique blend of cultural, historical, and natural attractions, making it an interesting study area for various fields like urban planning, sociology, and tourism.

3.1.2. Topography

Dire Dawa is located on a low land area in the Great East African Rift Valley. Dangago Mountain, with the peak altitude is located at South of Dire Dawa city in Oromia Regional State. In addition, there are other mountain chains located south of the city that surround the city in Southern direction. These include Kersa, Kulubi and Meta mountains located in the Oromia Regional State boundaries.

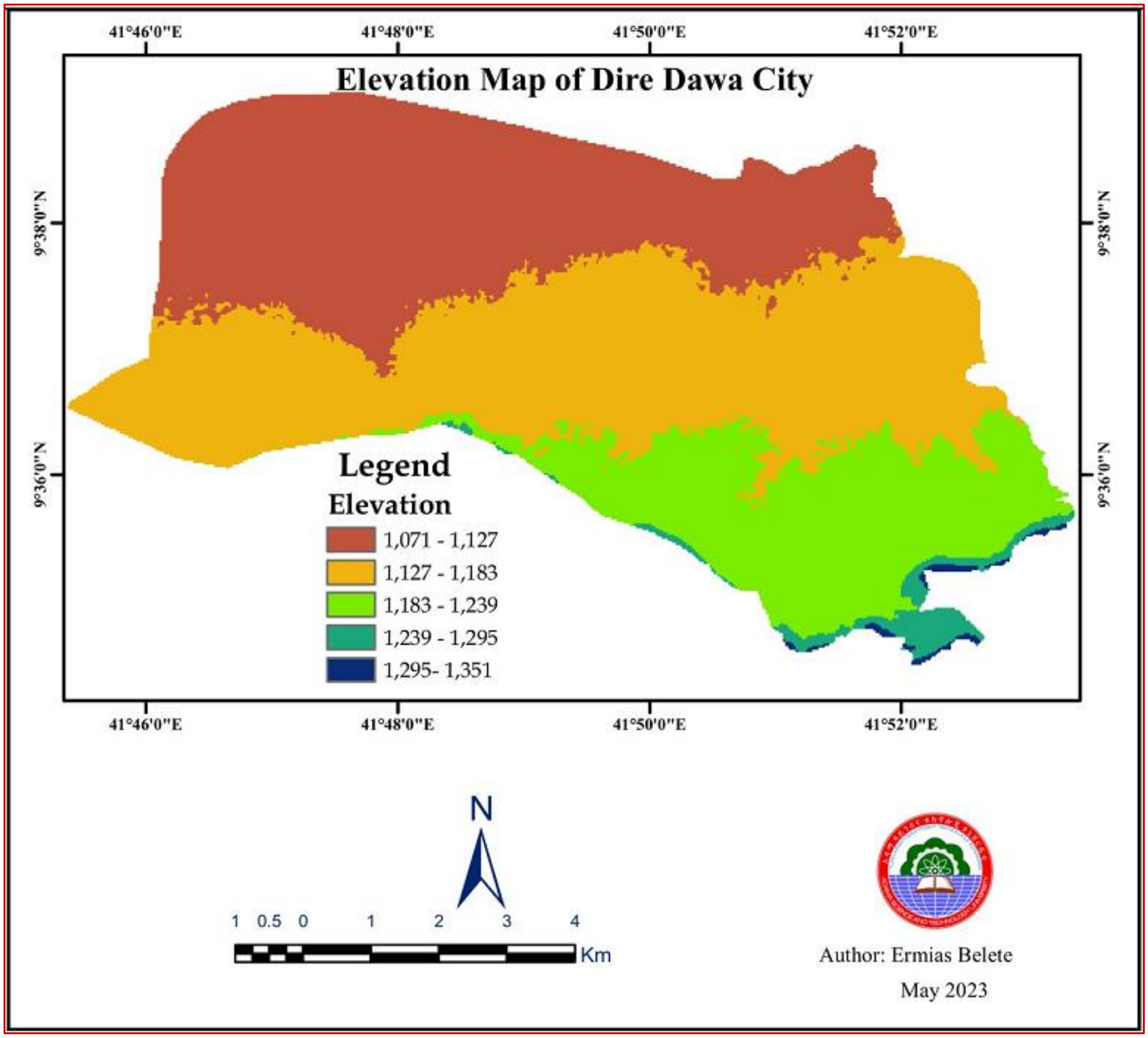


Figure 3.2: Elevation Map of Dire Dawa City (Source: Digital Elevation Model from INSA)

3.1.3. Population

Understanding the human population dynamics is extremely important when considering the impact of various human activities upon the trends of LULC and temperature either directly, indirectly, or both ways. While urbanization has been slow in Ethiopia, the recent growth rates have been spectacular. This rapid urban growth is also witnessed in Dire Dawa city. In 1995 the population of Dire Dawa was 180, 000 by the year 2000 it grew up to 229,000 an increase of 27 percent, by the year 2005 it went up to 284,000 an increase of 24 percent. It is currently estimated at 521000 people (CSA, 2012). Furthermore from public officials showed In terms of demographics, Dire Dawa is a diverse city with a population that includes different ethnic groups such as Oromo, Amhara, Somali, Gurage, Harari, and others. The multi-ethnic composition contributes to a rich cultural heritage and adds to the vibrancy of the city.

3.1.4. Economy

In the 1960s Dire Dawa's economy was booming due to the railway line, and the emergence of small and medium scale industries. It is only about 300 km from Djibout .With a view to fostering urban development and industrialization across the country, a report from public officials showed in 2015 the Ethiopian government announced a plan to establish ten industrial parks within five years (2015–2020), including one in Dire Dawa. Believed to be a gateway to achieving sustainable economic development through industrialization, these industrial parks facilitate the growth of secondary cities across the nation, including Dire Dawa. Economically, Dire Dawa is known for its industrial activities, including manufacturing, food processing, and textiles. The city also has a thriving agricultural sector, producing crops like chat, coffee, and fruits.

3.1.5. Climate

To understand the environment and the possible impact of human activity on it, a basic knowledge of weather and climate is required. The former is the physical condition of the atmosphere at a specific time and place concerning wind, temperature, cloud cover, fog, and precipitation. Despite its proximity to the Equator, the study area experiences a warm temperate climate. Ethiopia is located in the region where June through September is the main rainy season. Dire Dawa has a borderline tropical savanna climate just above a hot semi-arid climate. Dire Dawa has a semi-arid climate with distinct wet and dry seasons. The city's landscape is characterized by hills and plateaus, providing scenic views of the surrounding area. All climate diagrams on this page come from the collected data of the official weather station in Dire Dawa in a height of 1146m above sea level. All data correspond to the average monthly values of the last 20 years.

- ***Temperature***

The mean annual temperature of Dire Dawa is about 25.9 °C or 78.6 °F. The average maximum temperature of Dire Dawa is 32.8 °C or 91.0 °F, while its average minimum temperature is about 19.0 °C or 66.2 °F (NMI, 2022).

- ***Rainfall***

The region has two rain seasons; that is, a small rain season from March to April, and a more pronounced rain season that extends from July to August. The aggregate average annual rainfall that the region gets from these two seasons is about 670 millimeters or 26 inches (NMI, 2022).

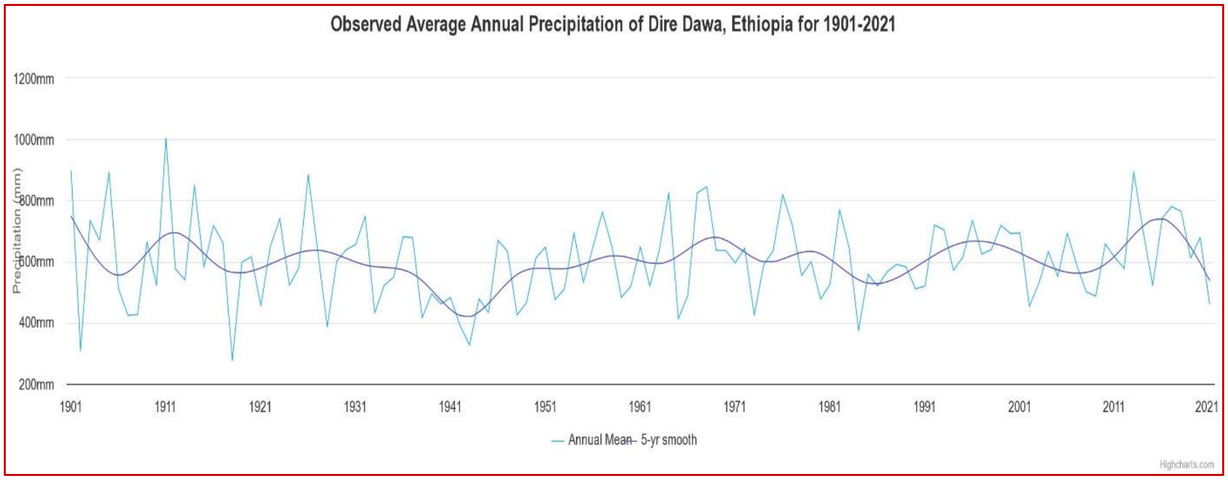


Figure 3.3: Average Annual Mean precipitation of Dire Dawa (1901-2021) (Source: NMI 2022)

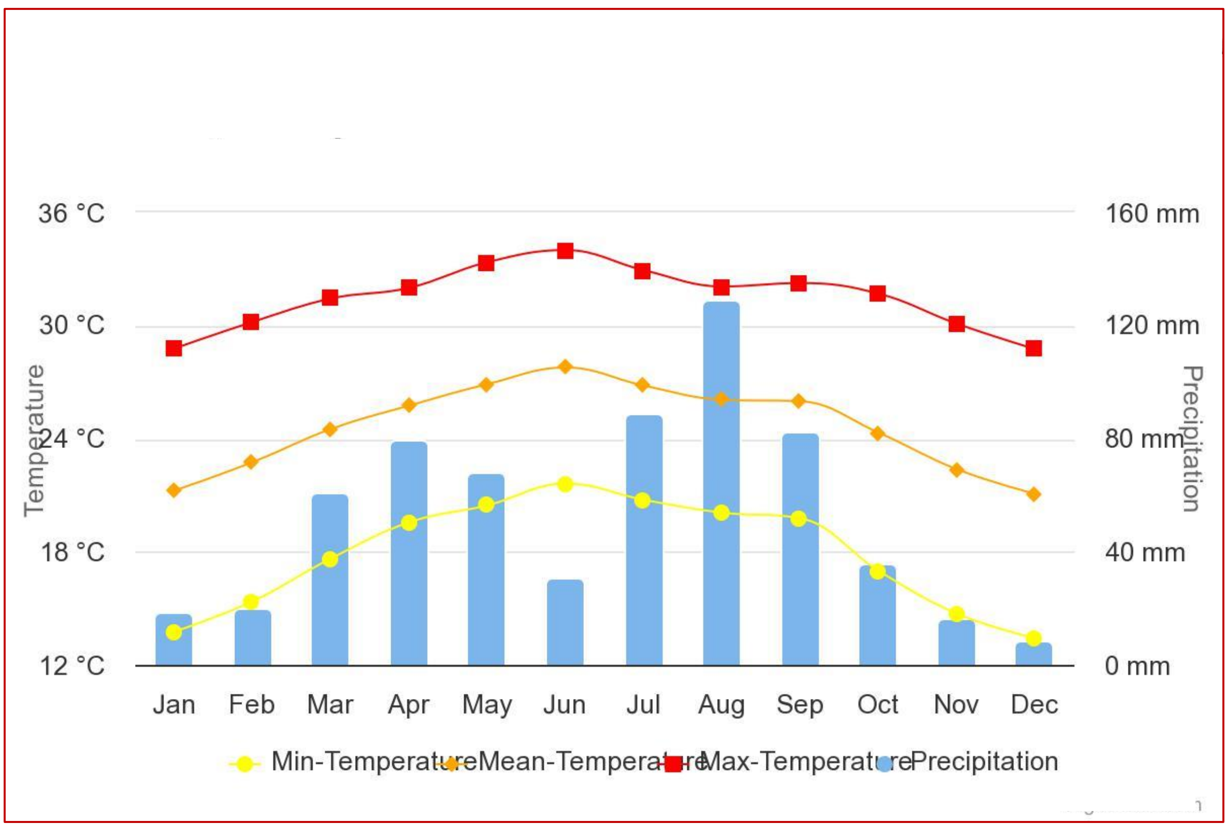


Figure 3.4: Average Monthly Min, Max, Mean Temperature, and Precipitation of Dire Dawa (1901-2020) (Source: NMI 2022)

At latitudes of 4 to 15˚N, Ethiopia's climate is typically tropical in the south-eastern and north-eastern lowland regions, but much cooler in the large central highland regions of the country. Mean annual temperatures are around 15-20˚C in these high altitude regions, whilst 25-30˚C in the lowlands (UNDP, 2007).

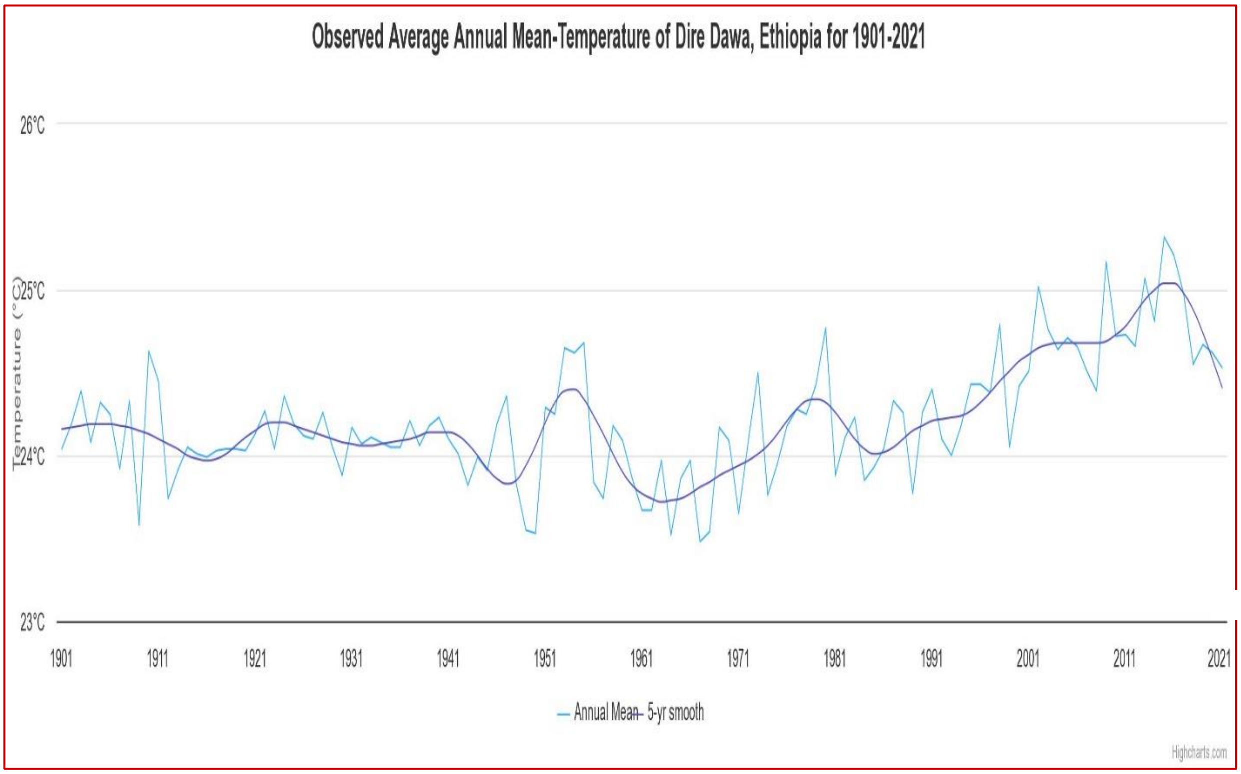


Figure 3.5: Average Annual Mean Temperature of Dire Dawa (1901-2021) (Source: NMI 2022)

3.2. Research design

Quantitative research designs were employed for all the data that was used in this study. Researchers have employed various research designs to assess and understand the relationships between urbanization, land use changes, and their impact on the microclimate. One commonly used design was correlational design, where the degree of association between LST and changes in land use and land cover was measured. This helps to identify patterns and trends in how urban development affects the local temperature and thermal comfort. Additionally, descriptive design approaches were employed to collect data through surveys, observations, or other methods to describe the characteristics of the population or phenomenon under investigation. The land use land cover of the study area change matrixes was done quantitatively and after that NDVI, the land surface temperature and UTFVI of the study area derived from Landsat image were done quantitatively, finally the results were taken for relationship and evaluation analysis.

3.3. Research Approach

The study employed combination of quantitative and qualitative approaches. So as to make the study holistic and increase the chance of saturation mixed (qualitative and quantitative) methods were utilized by the conductor of the study. Regarding the quantitative research approach, the researcher examined various variables and extracted data in numbers and statistics.

On the other hand a considerable amount of the study was approached using the qualitative research approach. In the qualitative research approach the researcher extracts data by observing and recording a certain situation. Therefore the conductor of the present study approached significant amount of the study using qualitative methods so as to deeply dig in to the topic.

3.4. Sampling Technique

The sampling method chosen for this research is stratified random sampling and purposive sampling. In stratified sampling, the populations are grouped together on the basis of similarity of spectral characteristics. Stratified random sampling is necessary to make sure that small, but important land covers are represented in the sample (Congalton, 1999). Each land cover and land use category was considered as a stratum. The study employed purposive sampling techniques to select dire dawa city because, dire dawa city is one of the largest cities in terms of area hosting many activities, but geographically urban surface temperature is relatively higher than other cities.

3.5. Sources and Types of Data

Data are the most important part of climate variability and/or change analysis and their acquisition is normally the costiest part of the analysis (Car, 2006). The study used a significant amount of primary data. This is because on the one hand the topic is a previously unstudied and new concept and on the other hand to keep the quality of reliability high. Accordingly, collected primary data was the main data of the conducted study. To achieve the stated objectives and answer the research questions the researcher collected data from both primary and secondary data sources using different data collection instruments from USGS earth explorer.

3.5.1. Primary Data Sources

The primary data source for this study is likely thermal images obtained from the United States Geological Survey (USGS). The study aims to investigate the impacts of urbanization-induced land use and land cover changes on land surface temperature and thermal comfort in Dire Dawa City, using seasonal and temporal data. Thermal images are likely to be an important source of information for this research, as they can be used to measure land surface temperature across different periods of time and in different seasons.

- *Satellite Imagery*

Landsat satellite imagery can be used to study the impacts of urbanization-induced land use land cover changes on land surface temperature and thermal comfort in Dire Dawa city using seasonal and temporal data. Landsat satellite imagery is used to study urbanization-induced land use changes and their effects on land surface temperature and thermal comfort due its high-resolution data and long-term data availability. By analyzing the satellite imagery, changes in land use and cover can be identified and correlated with changes in land surface temperature and thermal comfort. This analysis can help to identify areas of the city that may be experiencing higher temperatures and lower thermal comfort, allowing for targeted interventions such as green space development and building insulation improvements. The use of seasonal and temporal data can reveal changes in land use and cover, offering insight into the lasting effects of urbanization on the city's microclimate.

Since 1972, Landsat images have been accessible through three key sensors: MSS, TM, and ETM. These sensors have persistently provided images of the Earth's surface that exhibit multi-temporal, multi-spectral, and multi-resolution features, rendering them appropriate for land use and land cover analysis. In this study, three Landsat imageries from the years 2000, 2008, and 2022 were used to calculate and analyze land use land cover changes, land surface temperature, and the thermal ecological suitability (UTFVI) conditions and patterns of the city. Landsat 5 (TM) and Landsat 9 (TIRS) with 30m resolutions were employed for the purpose of conducting analysis for several reasons. First, the 30m resolution provides a good balance between spatial detail and coverage. This means that a larger area can be covered by the satellite imagery, making it suitable for regional or landscape-scale analysis. Additionally, the 30m resolution is often sufficient for many applications such as land cover classification, vegetation monitoring, and change detection. Using 30m resolution data also ensures compatibility and continuity with previous Landsat missions, allowing for historical analysis and comparisons. It's important to note that the choice of resolution depends on factors such as the scale and specificity of the analysis, the available computational resources, and the desired level of accuracy. The satellite images of early June and last march were chosen for this study as they represent the hottest and mostly cloud-free period in Dire Dawa. Remote sensing provides accurate area-wide data that can be quantified and mapped at relatively low costs, with quick, regular, and continuous surveillance observations.

Table 3.1: Satellite imageries and Specifications used in this study.

Satelllite Data	Sensor	Date Of Acquisition	Path/Row
Landsat 5	TM	26/05/2000	166/53
Landsat 5	TM	03/06/2008	166/53
Landsat 9	OLI/TIRS	06/06/2022	166/53

The selection of the study period, including the years 2000, 2008, and 2022, was based on significant turning points and available data for analyzing the urbanization process. The year 2000 serves as the baseline for this study, representing the initial state before significant urban expansion occurred in Dire Dawa city. By comparing land surface temperature and thermal comfort indicators in this year with subsequent years, we can identify the impact of urbanization on these variables. The year 2008 was selected as it represents an intermediate point between the baseline (2000) and the present (2022). This timeframe allows an analysis of the urbanization process during a crucial phase, helping to understand the extent of changes in land use and land cover and their associated effects on land surface temperature and thermal comfort. Lastly, the year 2022 represents the most recent available data for this study. By considering this endpoint, we can analyze the most up-to-date urbanization trends and their consequences on land surface temperature and thermal comfort. Understanding these current effects is crucial for identifying potential challenges and informing future urban planning strategies. These selected years provide valuable insights into the temporal dynamics of urbanization-induced land use and land cover changes and their impact on land surface temperature and thermal comfort in Dire Dawa city. Through this analysis, we can identify the turning points and trends in urbanization, shedding light on the implications for urban development, climate, and the well-being of the city's residents.

- *MODIS Data*

MODIS (Moderate Resolution Imaging Spectroradiometer) 11A2 data is a product that provides land surface temperature (LST) and emissivity data based on thermal bands of the MODIS instrument. This data product is processed into 8-day composites and has a spatial resolution of 1000 meters. In the day/night algorithm, daytime and nighttime LSTs and surface emissivities are retrieved from pairs of day and night MODIS observations in seven TIR bands. The product is comprised of LSTs, quality assessment, observation time, view angles, and emissivities. The MODIS 11A2 data is widely used for a variety of applications, including climate studies, the monitoring of land surface temperatures, and agricultural applications.

- *Google Earth Data*

Google Earth data was utilized in various ways for this study. Firstly, the Google Earth map was used as a base map to visualize and interpret corresponding data and images. Additionally, coordinates were extracted from the Google Earth map for sample points, which were selected based on a stratified sampling technique to verify land use and land cover (LULC) classes in different years. Furthermore, sample training points were extracted from the Google Earth map for supervised classifications. Finally, historical data were verified by comparing them with the results obtained from the classification of Google Earth data, as obtaining current on-the-ground data was impossible. Overall, the Google Earth data proved to be invaluable in verifying the accuracy of LULC classifications for historical data.

- *Field Observation*

In order to gather accurate data for the accuracy assessment and verification fields, the researcher conducted field observations on a selected site. The observation was completed in a natural setting, meaning that the conditions of the environment were not artificially manipulated or controlled. The researcher personally visited the site and observed the features of interest firsthand. It is important to note that the observation was conducted through convenience sampling techniques. This means that the researcher selected features to observe based on their availability and proximity to their location. Due to cost and other instrumental shortages, the researcher was unable to observe all of the features of interest on the site.

Despite the limited scope of the observation, the researcher made every effort to ensure the data collected was accurate and reliable. Through field observations, the researcher gained firsthand insight into key features that may not have been discernible through other data collection methods. The uncontrolled nature of the observation also ensured that the data gathered was representative of the conditions of the site in its natural state.

Overall, while the observations were completed through convenience sampling techniques, the researcher took great care to gather data as accurately as possible. By personally visiting the site and observing the features of interest firsthand, the data collected provides valuable insights into the accuracy and verification of the site.

3.5.2. Secondary Data Sources

In the present investigation, secondary sources refer to data that has been previously collected from primary sources and made accessible to researchers. This kind of information has already been gathered in the past. On the other hand some portion of the study utilized secondary data based on their availability. The secondary data sources were organizational records. The first inquiry is constituted of investigative data discovered in research papers and other relevant materials. Statistical data, prior research conducted by research institutions, and reports constitute the secondary data sources for this study. The inclusion of secondary data, in addition to primary data, facilitated the collection of evidence and provided responses to the research questions. Observed historical data on a daily and monthly basis for precipitation, maximum temperature (T_{max}), and minimum temperature (T_{min}) were obtained from the National Meteorological Institute (NMI).

3.6. Methods of data collection

The research was used primary and secondary data. The primary data was collected for the study area through field observation, ground control points, remote sensing data, and land cover field data. Secondary data was collected from various data sources. Satellite Image with the spatial resolution of 30 m used for land use land cover and it was downloaded from the website: www.earthexplorer.usgs.gov. Generally, both primary and secondary data was conducted in different phases.

3.7. Materials and software's

Different software packages were utilized to process the satellite images and analyze land-use and land-cover changes, normalized difference vegetation index, land surface temperature, and the urban thermal field variance index. A range of software was utilized in this study to accomplish these tasks and processes.

ERDAS IMAGINE 2014: was utilized for land use and land cover classification through the implementation of the maximum likelihood classification algorithm. This was accomplished through the utilization of training locations and the visual interpretation of the images.

ENVI 5.3: was employed for preprocessing procedures utilizing the Fast Line-of-Sight Atmospheric Analysis of Hypercube methodology.

Arc Map 10.8: was utilized for the analysis of satellite imagery, merging, dissolving, buffering, evaluating the results, and creating maps.

Google Earth pro: functioned as a tool to check and compare the outcomes with the ground truth, thereby enabling land use and land cover verification.

Zonal Statistics and Microsoft Excel 2013: were implemented to conduct statistical and regression analysis and to generate charts and graphs.

Microsoft Office and Microsoft PowerPoint: were employed to create word documents and for presentation purposes.

3.8. Methods of Data Analysis

3.8.1. Land Use Land Cover Classification

The spatio-temporal pattern of land use land cover in Dire Dawa city for two decades were analyzed from the Landsat images (TM and OLI/TIRS) data series of 2000, 2008, and 2022 using the ERDAS IMAGINE software by maximum likelihood as a supervised classification algorithm. There are three classified maps of land use and land cover classes, having four land classes including shrub land, built-up area, sparse vegetation, and barren-land classes of the study area (Figure 4.1). The classification is intended to produce land use land cover change for 22 years and compared against land surface temperature change.

- ***Data Pre-processing***

After the collection of data, it underwent a series of processes such as compilation, enhancement, stacking, processing, and interpretation to ensure its accuracy and logical coherence. Data preparation was then carried out to organize and align the datasets in a desired order for further analysis. The collected satellite images were subjected to various techniques, such as enhancement, stacking, and processing to facilitate interpretation and analysis. The descriptive method was used to analyze the processed data.

Present and past information on land cover and land-use change for the study area generated from remotely sensed data. Satellite images from Landsat for study period analyzed to calculate LULCC over the study area. The satellite images used in this study were classified into four land classes, namely; Built-up Area, Shrub land, Barren land, and Sparse Vegetation.

Table 3.2: Description of land-use land-cover classes with respective codes.

LULC Class	Code	Description
Built-up Area	BA	Areas dominated by manmade developments or features (residential, commercial, institutions, industries, recreational, utilities, roads and others)
Shrub Land	SL	Area which is covered with dense shrub, open shrub land, grasses and other short plants
Barren Land	BL	Open spaces, bare lands and soils, gave pits sands, dunes and excavation sites, Dry Rivers Which was dry for most of the year and became a torrent only when it rained of five major rivers, Dechatu, Goro, Laga Hare, Butuji and Melka Jabdu.
Sparse Vegetation	SV	Lands with a mosaic of forests, woody plants, trees, natural vegetation, gardens, parks and vegetated lands, agricultural lands, and crop fields

- ***Supervised Classification***

Supervised classification is the techniques most often used for the quantitative analysis of RS image data depending on their reflectance properties. It uses the spectral signature obtained from training samples to classify an image**.** In this study, supervised classification was used. Thus the researcher generates the spectral signatures of known categories and the software allocates each pixel in the image to the cover type to which its signature is most comparable, according to (Eastman, 2003). A sample of 200 for each 2000, 2008 and 2022 land use land cover classification, were Stratified randomly selected from the study area. After the training areas assigned for each class, classification activity was performed.

- ***Maximum Likelihood Classification Algorithm***

Maximum likelihood classification (MLC) is one of the most known methods of classification algorithm in remote sensing, in which a pixel with the MLC is classified into the matching classes or categories. It is a statistical decision measure to assist in the classification of overlapping signatures; pixels are assigned to the class (categories) of the highest probability. It was considered more accurate than parallelepiped classification algorithm. The MLC classification tool considers both the variances of the class signatures when assigning each cell to one of the classless represented in the signature file.

3.8.2. LULC Classification Accuracy Assessment

Accuracy assessment is an important part of any classification project that compares the classified image to another data source that is considered to be accurate or ground truth data (Esri, 2022). According to Esri (2022), ground truth can be collected in the field; however, this is time-consuming and expensive. Therefore, in this study interpreting optical imagery like Google Earth took ground truth data was used as a reference to check the accuracy of the classified image. The researcher used purposive sampling to select training sites, and 256 sample points were extracted using stratified random sampling techniques. As a result, the researcher classified the study area using kebele strata or boundaries. In the case of stratified random sampling, the number of samples has a positive relationship with accuracy.

Finally, using a confusion matrix, the kappa coefficient, user accuracy (accounting for errors of commission), and producer accuracy (accounting for errors of omission) were calculated for each year (Lillesand et al, 2015). The following formula was proposed for assessing accuracy:

Overall accuracy = $\frac{\text{Total no.of correctly classified pixels}}{\text{Total no.of reference pixels}} * 100$**........................**Eq. (1)

User Accuracy = $\frac{\text{No.of correctly classified pixels in each classes}}{\text{Total no.of classified pixels in that land classes}} * 100$ **.........**Eq. (2)

Kappa Coefficient (K) = $$\frac{\mathrm{N}(\sum_{i=1}^{r} \mathrm{xii}) - (\sum_{i=1}^{r}(xi+.x+i)}{N^2 - \sum_{i=1}^{r}(xi+.x+i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. \quad (3)$$

Where;

r= number of rows in the error matrix

Xii= number of observations in row i and column I (on major diagonal)

Xi+=total of observations in row i (shown as marginal total to right of the matrix)

X+i= total of observation in column i (shown as margin total at bottom of the matrix)

N= total number of observations included in the matrix

- ***Ground Truth***

A ground truth activity was carried out in the study area, in which different LULC classes would be validated. The LULC classes were used in producing the map and with the assist of Google Earth, training data used for image classification was acquired. During this ground truthing activities, photos of scenes of interest and coordinates from sample LULC classes were captured.

3.8.3. Land-use Land-cover change detection

Land-use land-cover change detection was done by involving images of study period**.** Using GIS techniques thematic images were compared. The cross-operation process of mapping LULCC over time began with mapping the satellite imagery.

Post classification is among the most widely used approach for change detection purpose (Chen, 2000). The analysis of LULCC maps involved technical procedures of integration using the ArcGIS software techniques. The first task is to develop a table indicating the area coverage in square kilometers and the percentage change for each year measured against each LULC classes. Therefore, to calculate LULC change in percentage equation (eq.4) was used (Lambin et al, 2001).

$Percentage\ change\ of\ each\ LULC\ class = observed\ change\ /\ area\ sum * 100$**………**Eq. (4)

3.8.4. Vegetation Abundance Analysis through NDVI

The NDVI is the most common measurement used for measuring vegetation cover. Landsat Normalized Difference Vegetation Index (NDVI) is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health (USGS). It ranges from values -1 to +1. Very low values of NDVI (-0.1 and below) correspond to barren areas of rock, sand, or urban/built-up. Zero indicates the water cover. Moderate values indicate sparse vegetation (0.1 to 0.3), whereas high values suggest dense vegetation (0.6 to 0.8).This was calculated as Eq. (5):

NDVI = (NIR-Red)/ (NIR+Red) **…………………………………………………….**Eq. (5)

Where;
- NDVI: Normalized Difference Vegetation Index
- NIR: Reflectance in Near-infrared band
- Red: Reflectance in the red band

Due to the band composition variations between different Landsat versions, it is obvious to have differences in the band reflectance measurements. See below how to calculate the NDVI for different Landsat data: **In Landsat 4-7, NDVI** = (Band 4 – Band 3) / (Band 4 + Band 3).

In Landsat 8-9, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).

3.8.5. Land Surface Temperature Analysis

The surface temperature was retrieved using the thermal band(s) of Landsat imageries. To calculate the land surface temperature, radiometrically corrected thermal infrared bands of Landsat images basically Landsat TM and ETM+ band 6 (thermal infrared band) and Landsat 9 band 10 (thermal infrared band) were used to estimate terrestrial surface temperatures by converting Digital Numbers (DNs) into radiance. According to Avdan and Jovanovska (2016) LST of the study was calculated as Eq. (6):

$$\text{LST} = \frac{\text{BT}}{\{1+\left[\left(\frac{\lambda\text{BT}}{\rho}\right) ln\ \varepsilon\lambda\right]\}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq.(6)$$

Where;

LST: Land Surface Temperature in Celsius ($^{\circ}C$)

BT: satellite temperature (at sensor) ($^{\circ}C$)

λ: is the wavelength of emitted radiance

ρ: Constant value obtained by the formula $\rho = h * (c/\alpha) = 1.438 * 10^{2}$ mk

Ɛλ: is the emissivity

❖ *DN Conversion to Radiance*

The Landsat data user handbook can be used to convert the image's Digital Numbers (DNs) to the spectral radiance of the top of the atmosphere (USGS, 2021). To obtain radiance from Landsat 5 DN, the subsequent equation was utilized:

$L\lambda = (LMAX - LMIN) / (QMAX - QMIN) * (DN - QMIN) + LMIN$ ……..*Eq (7)*

Where Lλ is the spectral radiance, LMAX is the maximum radiance, LMIN is the minimum radiance, QMAX is the maximum DN value, QMIN is the minimum DN value, and DN is the pixel value.

The metadata of the Landsat 5 image contains values for LMAX, LMIN, QMAX, and QMIN.

Digital numbers can be converted to Radiance for Landsat 9 using a specific formula:

$L\lambda = (DN * Qcal) + AL$…………………………………………………*Eq (8)*

Where Lλ is Spectral Radiance (W/m2 Sr µm), DN is Digital Number, Qcal: Quantized and calibrated standard product pixel values (specified in the metadata file), AL: Band specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number).

After calculated the spectral radiance, it can be converted to surface reflectance using the appropriate coefficients and atmospheric correction methods.

❖ *Radiance Conversion to Temperature*

The general equation for converting radiance to temperature for Landsat 5 and 9 is: Temperature (T) = K2 / ln (K1 / Radiance + 1)-273.15…………………….…………*Eq (9)*

Where T: Brightness temperature in Celsius, K1 and K2 are constants specific to the Landsat sensor and can be found in the metadata of the image. For Landsat 5 TM, the spectral radiance of Band 6 (Thermal Infrared or TIR) and For Landsat 9, Band 10 (TIRS 2) can be converted to temperature using the above equation and the given equation is subtracted by 273.15 to convert temperature from kelvin to Celsius.

❖ *Land Surface Emissivity (LSE)*

Land surface emissivity, is a measure of how efficiently the Earth's surface emits thermal energy through infrared radiation. To calculate LSE, the radiance of the Earth's surface is measured in two different spectral bands, one in the atmospheric window and the other in the absorption band, taking into account variations in radiance caused by atmospheric water vapor and other gases. LSE is expressed as a ratio of the energy radiated by the Earth's surface compared to that of a blackbody at the same temperature.

As outlined in a study conducted by Skokovic et al. (2014), the average emissivity of an element on the Earth's surface is determined by calculating vegetation proportion values or the degree of vegetation coverage as per equation 10.

PV = [(NDVI - $NDVImin$) / (N$DVIm$ax- $NDVImin$)] ^{2}……………....Eq. (10)

Where;

PV = proportion of vegetation

NDVI = DN values from Normalized Difference Vegetation Index image

$NDVI_{min}$ = minimum DN values from Normalized Difference Vegetation Index image

$NDVI_{max}$ = Maximum DN values from Normalized Difference Vegetation Index image

Then the value of the emissivity, as a last step, is obtained through the following (Eq.11):

e = $m * PV + n$ ……………………………………………………….. $Eq.$ (11)

Where;

e = Land surface emissivity

m = value of emissivity of vegetation, in this case 0.004 was used

PV = proportion of vegetation

n = Soil emissivity value, in this case 0.986 was used

- ***Land Surface Temperature Evaluation***

The extracted land surface temperature (LST), i.e., extracted from Landsat 5 TM (2000, and 2008), and Landsat 9 OLI/TIRS (2022), was evaluated using MODIS 11A2 data. This validation is based on land surface temperature results for the year 2022 for both satellite sensors.

The MODIS land surface temperature and emissivity products at 1 km spatial resolution and 8-day temporal resolution were retrieved in the Hierarchical Data Format (HDF-EOS), which can be accessed from the USGS Earth Explorer website. This HDF format was converted to an image format using ArcGIS software.

3.8.6. Thermal Comfort Assessment through UTFVI

Urban environment from the perspective of ecology of any location was analyzed using the index of Urban Thermal Field Variance Index (UTFVI). The thermal and ecological aspects of Dire Dawa was addressed in this paper, which has never been studied previously. It was studied using the Urban Thermal Field Variance Index (UTFVI), which is the most widely used statistic for evaluating urban environments from an ecological perspective (Naim and Kafy, 2021; Abir et al., 2021; Al Faisal et al., 2021).

UTFVI = LST-Tm/Tm ………………………………………………………… $Eq.$ (7)

Where;

- UTFVI: Urban Thermal Field Variance Index
- LST: Land Surface Temperature (LST) of pixel
- Tm: The mean LST of the area.

Table 3.3: Threshold UTFVI value for ecological evaluation and thermal comfort.

Urban Thermal Field Variation Index (UTFVI)	Ecological Evaluation Index (EVI)
< 0	Excellent
0 - 0.005	Good
0.005 - 0.010	Normal
0.010 – 0.015	Bad
0.015 – 0.020	Worse
> 0.020	Worst

Source: Abir et al (2021).

3.9. Statistical Analysis

The researcher assessed the land use and land cover quantitatively. The study also used two commonly known indices, named NDVI and NDBI, to establish the correlation with the land surface temperature in Dire Dawa. These indices were used to establish quantifiable relationships with LST through the correlation function. The statistical relationship was implemented using the ArcGIS and Excel 2013 software and tool packages. ArcGIS is a powerful geographic information system software that is widely used for spatial analysis and mapping. It offers various tools and functionalities for analyzing spatial data and performing statistical analyses. One such method is map algebra, which allows users to perform mathematical operations on raster datasets, such as adding, subtracting, or multiplying them. In the context of statistical analysis, map algebra can be used to combine multiple raster datasets, compute statistical summaries, or generate derived raster layers based on certain criteria. This can provide insights into spatial patterns, relationships, and trends within the data.

Additionally, zonal statistics analysis is a method used to summarize and compare raster data within predefined zones or regions of interest. This analysis can provide aggregated statistics, such as mean, maximum, minimum, or total values, for specific areas of a raster layer. In summary, the utilization of ArcGIS and Excel 2013 software for statistical analysis involves employing map algebra techniques for spatial data manipulation and deriving insights, as well as utilizing Excel's statistical functions for analyzing non-spatial data.

3. 10. Methodological Workflow

The methodology used in this study is to utilize Geographic Information System and thermal remote sensing of satellite imagery through preprocessing and processing data by means of image enhancement, haze correction, georeferencing and supervised the classification of each land use type using ERDAS imagine software, and on the other hand the NDVI, LSE, LST, UTFVI values were determined and analyzed to produce LULC, NDVI, LST, UTFVI maps on ArcGIS. Confidentiality of correlation was determined so as to yield good results in impacts of urbanization-induced LULCC on LST and thermal stress for the study area. The following schematic flow chart depicts the overall procedures.

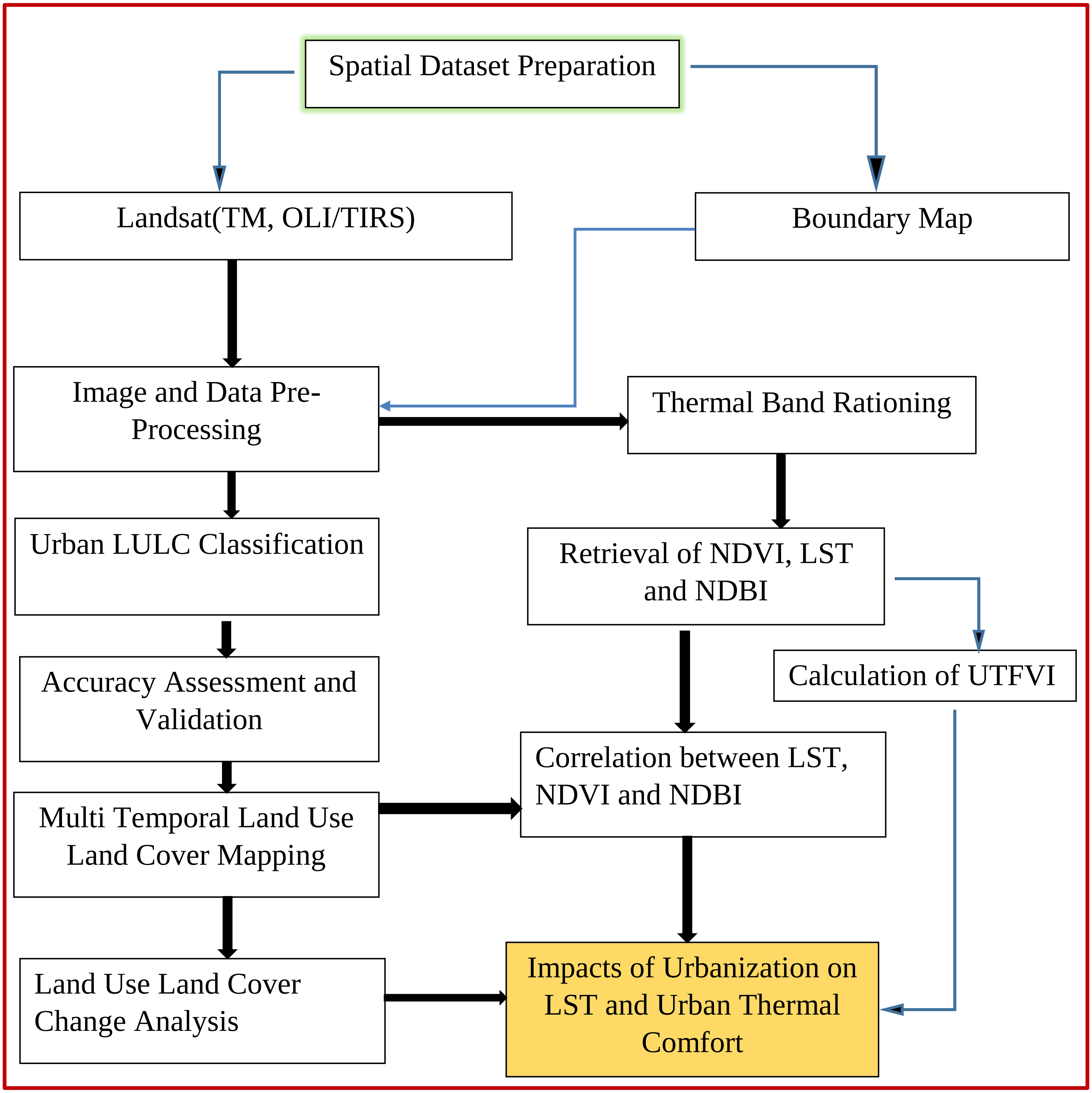


Figure 3.6: The methodological flow of the Study. (Source: Adapted from a review of the literature and my own Articulation, 2022).

CHAPTER IV: RESULTS AND DISCUSSIONS

This chapter analyzed and discussed the results of data collected primarily through remote sensing (Landsat satellite image, Google Earth, and MODIS). Accordingly data's were preprocessed, coded, classified, and tabulated. This is mainly to find out the main objective of the research, which is to assess and analyze the LULCC impact on LST, and thermal comfort (UTFVI) of Dire Dawa city. Using remotely sensed Landsat data images, Google Earth, MODIS, and observations this chapter assesses, presents, and discusses the spatio-temporal change in LULC and its implications for LST and UTFVI for the city of Dire Dawa and presented in the form of tables, graphs, percentages, and maps. The findings were organized according to the study's objectives.

4.1. LULC Classes Distribution

4.1.1. Spatio-Temporal Analysis of LULC

During the year 2000, Land-use land-cover classification result showed that the dominant LULC classes were shrub land. These classes accounted for 39.1% of the overall area coverage. From the total area of 69 sq.km, barren land accounted for 17 sq.km (24.6%) and urban settlement accounted for 17 sq.km (24.6%). The other LULC sparse vegetation accounted for 11.6 sq.km (15.06%) of the total area. The sparse vegetation covered the smallest area than all other classes. Spatially in this year, the western, central and northern part of the city was dominated by shrub and barren land, while sparse vegetation was distributed across southern part including along the dry rivers in the city. The built-up area was mostly concentrated in the eastern part of the city.

Analysis of 2008 image also showed that shrub land constitutes the largest proportion of land in the study area with the value of 35 sq.km (50.7%), followed by built-up area, which accounted 18 sq.km (26.1%). On Other hand barren land and sparse vegetation LULC synonymously accounted for 11.6% of the total area. Accordingly the shrub land class was expanded, especially in the western part of Dire Dawa (Figure 4.1A to 4.1B). However, after the year of 2008, it began to decrease wisely (Figure 4.1C). This is due to the sharp urban development of the city, which accounted in the need for extra land for urbanization activities.

Land-use land-cover classification results from 2022 image highly revealed that the dominant LULC categories was built-up area accounted for 27 sq.km (39.1%) of the total area coverage. shrub land accounted for 25 sq.km (36.2%) in 2022. Other LULC classes were sparse vegetation accounted 13% and barren land accounted for 11.6% of the total area. .

The three-year LULC map of the city shows the expansion of built-up areas at the expense of the other land classes. Thus, the expansion and shrinking phenomena of LULC take place throughout all directions of the city except in some an eastern part. LULC changes of 22 years were calculated to point out the rate of change and conversion. Detailed statistical data for each of these classes and LULC map of the study period were shown in Table 4.1and Figure 4.1.

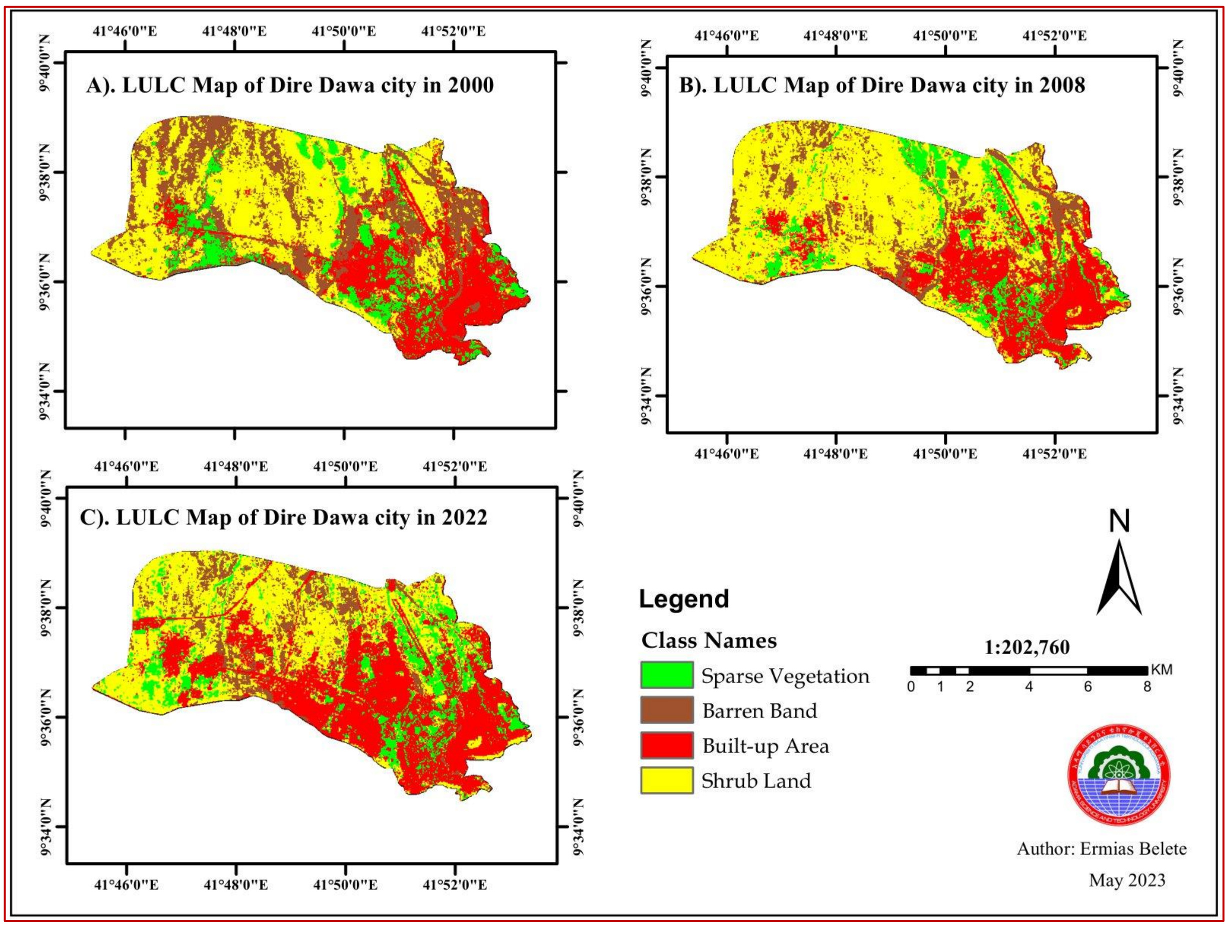


Figure 4.1: The LULC map of Dire Dawa city (2000 to 2022).

The analysis of the change in sub-city based LULC classes in the study area was shown in Figure 4.2. The city's administrative boundaries are delineated into sub-city levels based on the current administrative structure, which is compiled from various open sources and may not be authoritative. In the year of 2000 shrub and barren land class were concentrated over 01 (Melka Jebdu), 02 (Sabiyan, Goro, Genede Tesfa), and in relatively small amount of cover in 03 (Kezira, Numberone, Sefere Selam) sub cities of the study area. In that year the built-up land class was covered others sub cities (Figure 4.2A). As shown in the Figure 4.2B, the shrub and barren land were highly decreased from the year 2000 to 2022 because of built-up area increment.

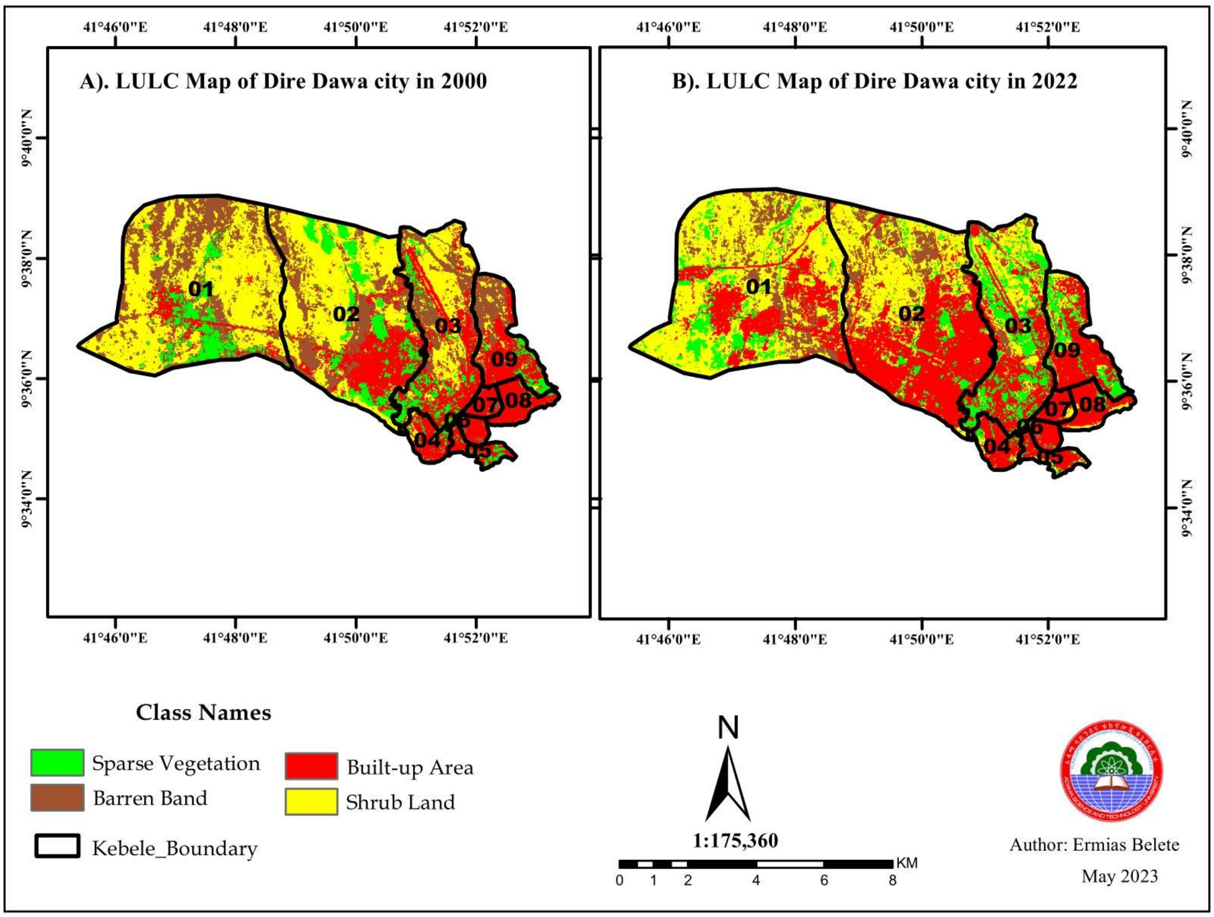


Figure 4.2: Kebele level LULC map of Dire Dawa city (2000 to 2022).

The researcher argued that due to the uncontrolled horizontal expansion of Dire Dawa city, other land categories in the city, such as shrub land, barren land and sparse vegetation land cover, which have a significant impact on controlling urban ecology, were aggressively affected. This is mainly with the increasing need of more land for development purposes.

4.1.2. LULC Area Statistical Analysis

The change in land use and land cover due to the various anthropogenic activities or uses of land during the period under consideration is summarized quantitatively in Table 4.1. Land-use land-cover patterns in the study area have indicated a significant change in between 2000 and 2022 years. Among the four major LULC classes, shrub land and urban settlement together covered greater percentage of the area in all the study years. Urban settlement has been increasing from 2000 to 2022. It has increased from 24.6% in 2000 to 26.1% by 2008 and 39.1% in 2022. The sparse vegetation of the study area was remained constant with a little increment throughout the study period (Figure 4.3). From the year 2000 to 2022, shrub and barren land showed decrement. Shrub land was 39.1% in 2000, which decreased to 36.2% by 2022, and barren land was 24.6% by 2000, decreased to 11.6% in 2022 (Table 4.1). In the year 2022, built-up area was increased by 10sq.km area from 2000 year at the expense of barren and shrub land for the last two decades. The general statistical representation of the area (km^2) and percentage coverage of land use land cover classes in the city from the period of 2000 to 2022 is shown in Table (4.1) and Figure (4.3).

Table 4.1: Quantitative area coverage of each LULC classes in Dire Dawa (2000 to 2022).

LULC classes	**2000**		**2008**		**2022**	
	Area(km^2)	%	Area(km^2)	%	Area(km^2)	%
BA	17	24.6%	18	26.1%	27	39.1%
SL	27	39.1%	35	50.7%	25	36.2%
BL	17	24.6%	8	11.6%	8	11.6%
SV	8	11.6%	8	11.6%	9	13%
Total	69	100%	69	100%	69	100%

Where; BA= Built-up Area, BL= Barren Land, SV=Sparse Vegetation, SL=Shrub Land.

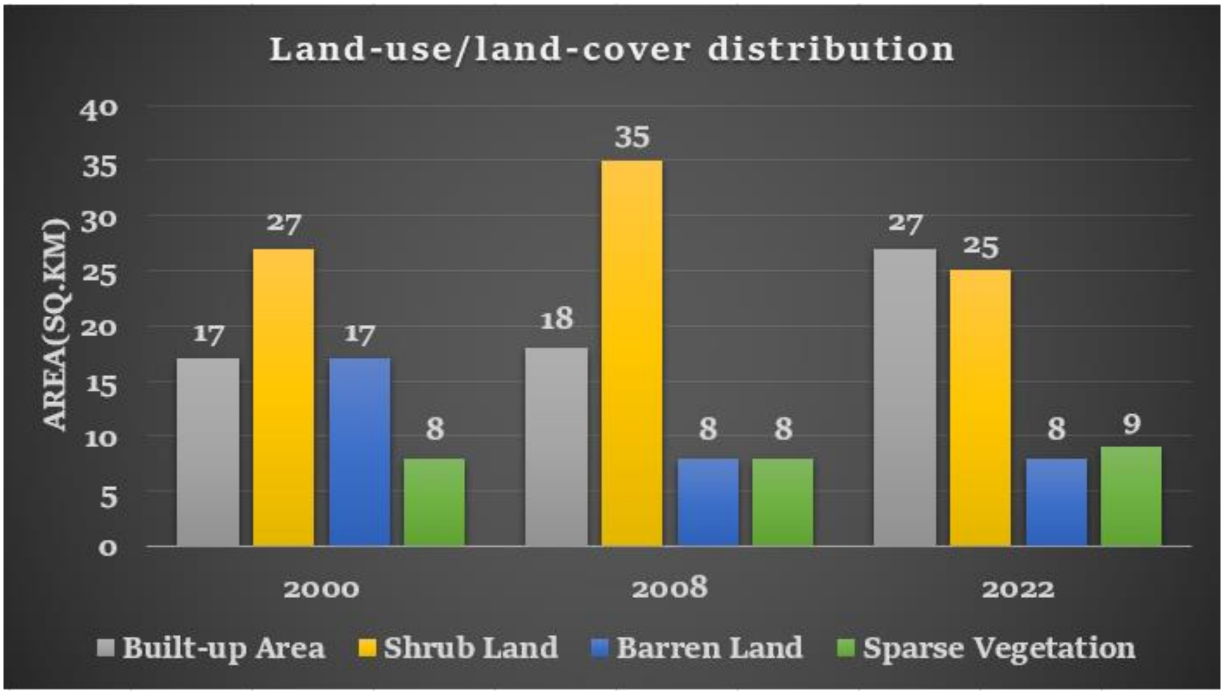


Figure 4.3: The area coverage of each LULC classes in Dire Dawa city (2000 to 2022).

Gain and Loose

The land use changes were evaluated by gains and losses of different classes (figure 4.4). Most of the classes have both gains and losses. The statistical change in Table 4.2 shows the amount of land in km^2 that has been converted to or gained from other LULC classes. Between 2000 and 2008, shrub land and built-up land use classes expanded significantly at the expense of barren land while sparse vegetation was remained constant. Thus, within the time interval (2000 to 2008), $9km^2$ of bare land were converted to shrub land and built-up. Furthermore, from 2008 to 2022, the sparse vegetation and built-up classes gained 1km2 and $9km^2$ of land, respectively, from the shrub land classes. Despite this, between 2008 and 2022, $10km^2$ of shrub land cover was converted to the sparse vegetation and built-up classes while bare land was detected with no change. In the years between 2000 and 2022, $9km^2$ and $2km^2$ of bare and shrub land respectively were gained by sparse vegetation and built-up categories.

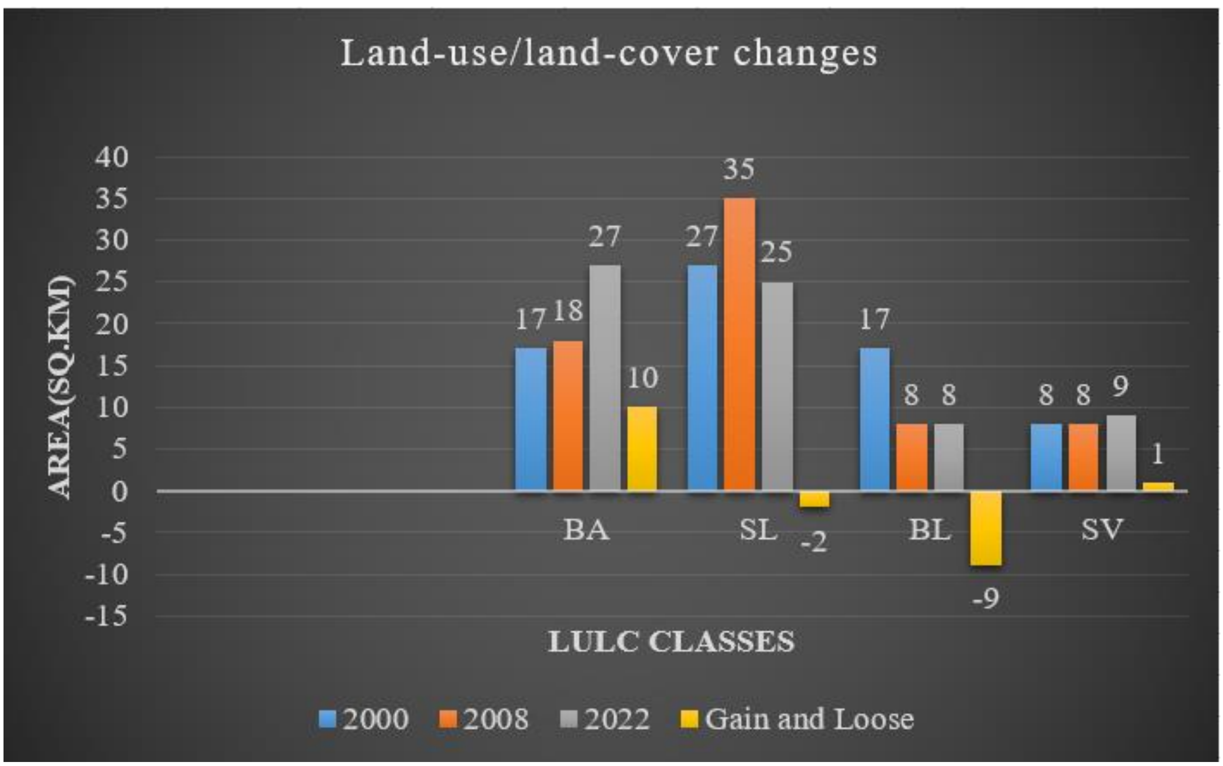
Thus, the built-up classes' cover expanded noticeably, which gained about $10km^2$ land from bare land, and shrub land cover categories. The researcher's argument for expanding vegetation land in the city is corresponding to an increase in tree planting in the city, urban gardening, parks, and greenery areas.

The past decadal governmental activities of dressing the land by greenery and even the currently green legacy governmental level advocacies have their own impact.

Table 4.2: The LULC class's area coverage change Gain and Loose (2000 to 2022).

LULC Classes	Change during 2000- 2008		Change during 2008-2022		Change during 2000-2022	
	Area(km²)	%	Area(km²)	%	Area(km²)	%
BA	+1	+1.5%	+9	+13%	+10	+14.5%
SL	+8	+11.6%	-10	-14.5%	-2	-2.9%
BL	-9	-13%	0	0	-9	-13%
SV	0	0	+1	+1.4%	+1	+1.4%

Where; BA= Built-up Area, BL= Barren Land, SV=Sparse Vegetation, SL=Shrub Land.



Where; BA= Built-up Area, BL= Barren Land, SV=Sparse Vegetation, SL=Shrub Land.

Figure 4.4: Land-use/land-cover changes in Dire Dawa city (2000—2022).

According to the analysis, the transformation of sparse vegetation covers into other land use is not detected in the city. This is due to two factors. The first is that the majority of the areas with vegetation cover, particularly those covered by sparse forests, are only found in areas with mountainous terrain, river sides, and no infrastructure development there. The second is the government's green development policy and green legacy advocacy, as well as the protection of these forest-covered areas, and by planting additional trees to cover the open space with forest. However, the city's expansion and rising demand for land continue to have a significant impact on the city's forest cover and health.

On the other hand, over the last two decades, the transformation from shrub and bare land to built-up land use has been increasing. This could be because they are mostly found on flat, accessible, and suitable terrain for development purposes, such as infrastructure, industries, and low-cost housing. For example, the city's shrub land was concentrated in the relatively flat areas of the city's northern, south western, central and western parts. This result is also consistent with recent research findings, which state that natural land cover is rapidly being replaced by built-up areas. The visual representation of these land use and land cover changes with time series data, shown in Figure (4.2), can also articulate this change. It demonstrates that the amount of built-up area was lower in 2000 and increased over time (2022), with the area becoming red in color (as the built-up area is symbolized as red).

4.1.3. LULC Classification Accuracy Assessment

The accuracy assessment of LULC for the years 2000, 2008 and 2022 was analyzed. The accuracy assessment results in Table (4.3) show that the overall accuracy obtained from the random sampling process for the 2022 satellite image is approximately 88.28%. For the land classes of built up area, shrub land, barren land, and sparse vegetation, the user's accuracy accounts 86.55 %, 94.00%, 87.50%, and 89.47% respectively. Thus, the range of user accuracy is ranges from 86.55% to 94.00%. Shrub land, on the other hand, was found to be relatively more reliable, with 94.00% user accuracy.

The commission error reflects the points that are in the category but do not actually belong there. For example, the commission error is the highest in the case of sparse vegetation classes, implying that a greater number of points that do not fall into this category are classified as sparse vegetation classes (Table 4.3).

Similarly, the omission error represents the number of points that are not included in the category even though they should be. The omission error in the case of Built-up area is more points, which actually belong in this category but are not categorized in this class. The overall Kappa coefficient in this study was approximately 0.7871, which is recognized as excellent classification.

Table 4.3: The accuracy assessment error matrix (2022).

	Class types determined from reference sources						**User Accuracy**	**Kappa statistics**
Class types determined from classified map	**Class Name**	**BA**	**SL**	**BL**	**SV**	**Total**		
	BA	148	7	6	10	171	86.55 %	0.6721
	SL	1	47	2	3	50	94.00%	0.9236
	BL	1	0	14	2	16	87.50%	0.8632
	SV	1	1	0	17	19	89.47%	0.8818
	Total	151	55	22	28	256		
Producer Accuracy		98.01 %	85.45 %	63.64 %	60.71 %		88.28%	
Over All Accuracy	**88.28%**							
Over All Kappa Statistic	**0.7871**							

4.2. Vegetation Abundance Analysis through NDVI

The researcher employed NDVI to portray vegetation coverage, as shown in Figure (4.5). The result in Figure (4.5) showed that part of northern, eastern, northwestern, and river bank areas of Dire Dawa had higher NDVI values (0.52) in 2000. However, most parts of the city, had low NDVI values in 2000. Similarly, in the year 2022, almost all parts of Dire Dawa, except some parts of the city, had experienced low NDVI values. As a result, NDVI values were higher in 2000, with a maximum value of 0.52, than in 2022, with a maximum value of 0.38. This implies that there was more healthy vegetation cover in 2000 than in 2022. The highest value shows healthy vegetation. Normalized difference vegetation index result for the years 2000, 2008 and 2022 were presented in Figure 4.6.

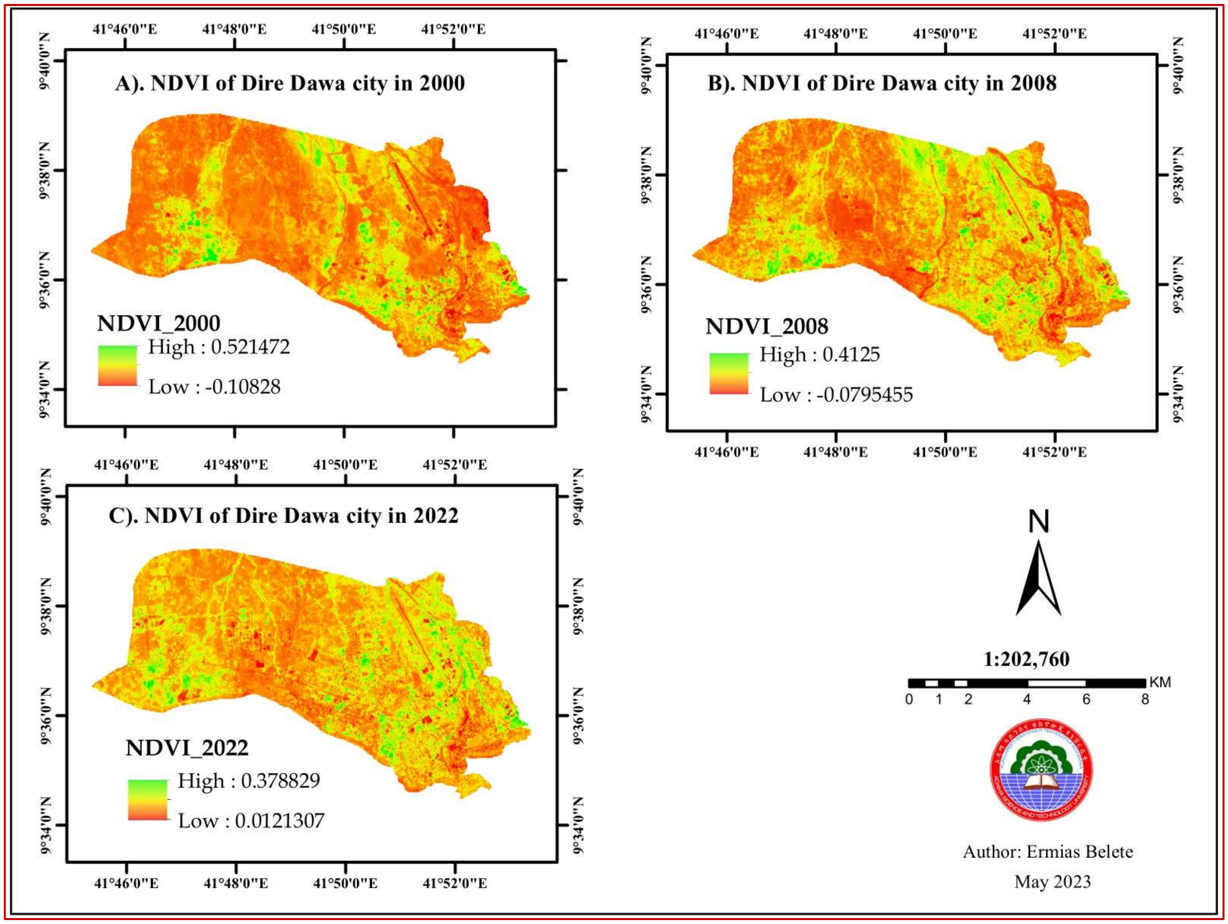


Figure 4.5: The spatio-temporal pattern of NDVI in Dire Dawa (2000 to 2022).

Table 4.4: Statistical pattern of NDVI in Dire Dawa (2000 to 2022).

NDVI	2000	2008	2022
MIN	-0.10828	-0.0795455	0.0121307
MAX	0.521472	0.4125	0.378829
MEAN	0.0715	0.0949	0.1559
STD	0.0558	0.0556	0.0365

Where: MIN = Minimum, MAX = Maximum, STD = Standard deviation

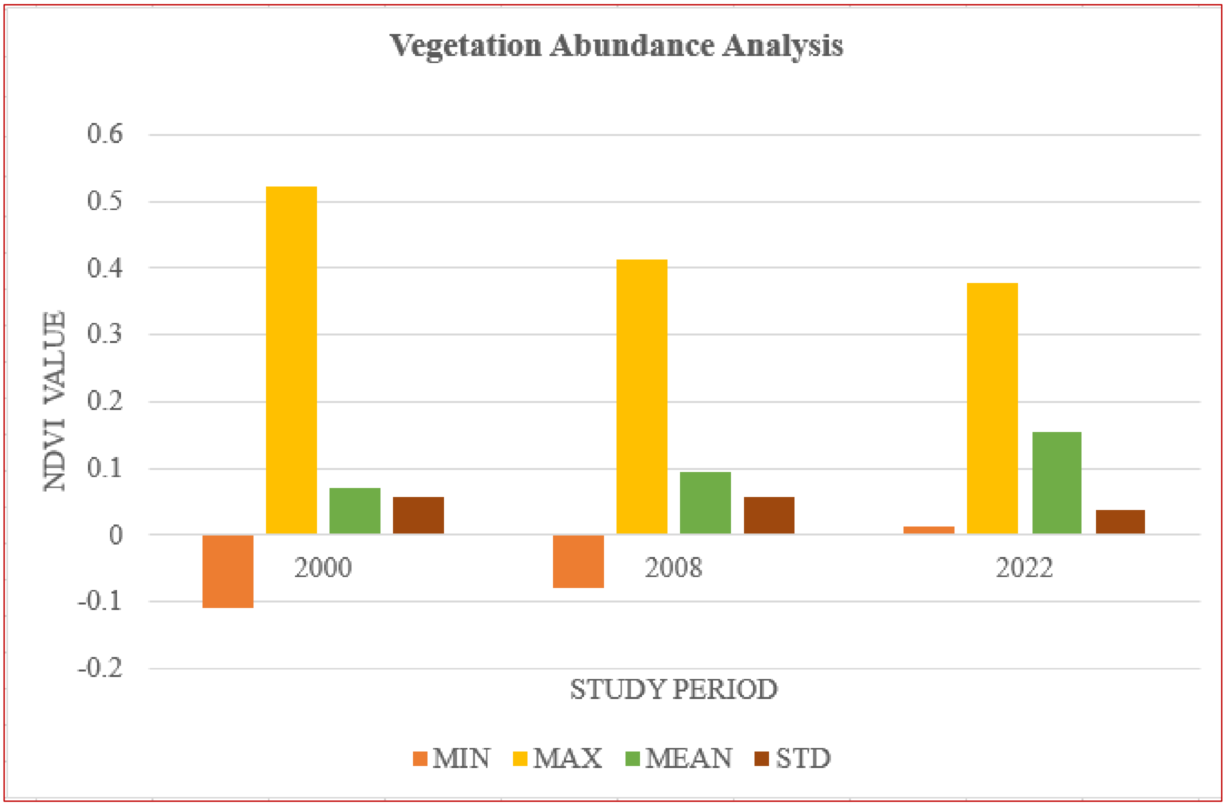


Figure 4.6: The statistical pattern of NDVI in Dire Dawa (2000 to 2022).

In the Figure 4.6, it is illustrated that the NDVI value of the city has decreasing at the decreasing rate in the previous two decades i.e., from 0.52 in 2000 to 0.38 in 2022. This plays undeniable role in eliminating cooling effect in the city by exposing the land to solar radiation.

4.3. Distribution of LST and its responses to LULC types

The spatial distribution of LST of the study area was extracted and quantified using Landsat TM of 2000, 2008 and OLI/TIRS of 2022 thermal bands. The analysis from such images indicated that the LST value of the study period ranged from 19.7°C to 43.3°C as it was observed from the processed thermal images.

Figure (4.7) represents the spatial-temporal distribution map of LST in Dire Dawa from 2000 to 2022. It is clear that the spatial variance of the LST has changed over the study area's two decades. Using visual interpretation techniques, the intensities of the LST were mostly increased in the land classes of bare land, shrub land, and built-up land class of Dire Dawa. The main reason behind less NDVI and high ST values in these area of LULC class is that the image was taken during the dry season and during harvesting time.

In 2000, for example, high temperatures were recorded in the city's western, central and northern parts. Those areas of the city were primarily were shrub land at that time, and some were covered in bare land that is exposed to direct incoming radiation. Those parts which were relatively or dominantly covered by vegetation has recorded relatively low surface temperature. Similarly, with the expansion of built land class at the expense of other uses of land in the city for the past two decades, encountered a significant increase in LST intensity. In addition to this within the same land use land cover class, there is a variation in the value of LST.

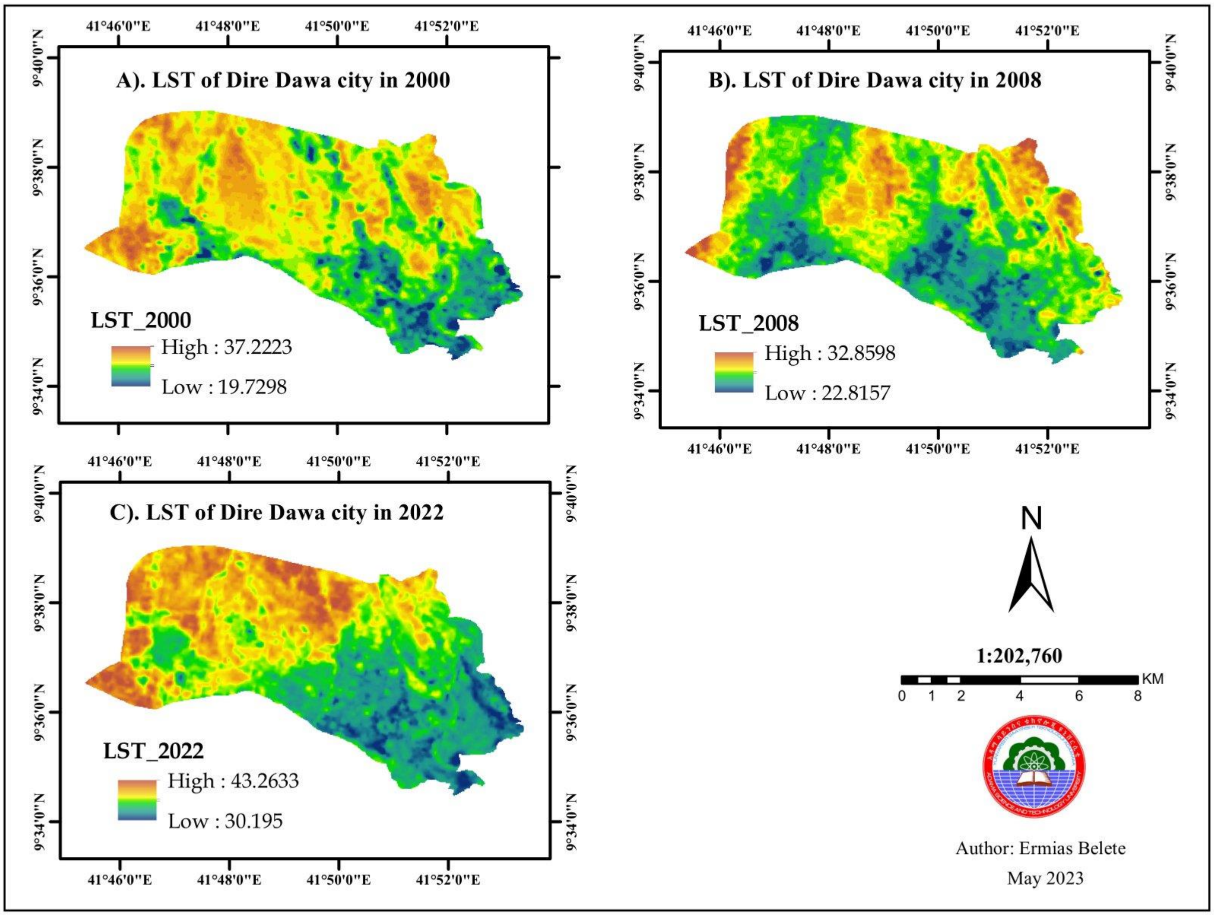
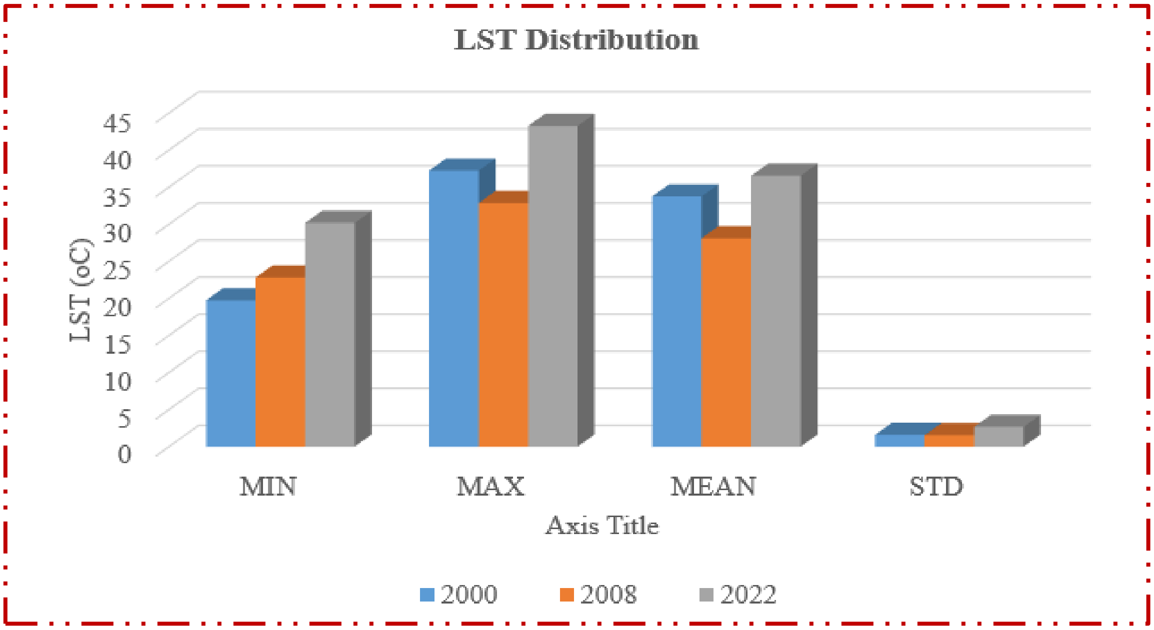


Figure 4.7: The spatial and temporal variation of LST (°C) in Dire Dawa (2000 to 2022).

Table 4.5: Temporal variance in LST (oC) in Dire Dawa (2000 to 2022).

LST (°C)	**2000**	**2008**	**2022**
MIN	19.7298	22.8157	30.1950
MAX	37.2223	32.8598	43.2633
MEAN	33.7411	28.1044	36.5482
STD	1.5892	1.5395	2.6706

Where: MIN = Minimum, MAX = Maximum, STD = Standard deviation



Where: MIN = Minimum, MAX = Maximum, STD = Standard deviation

Figure 4.8: Statistical pattern of LST in Dire Dawa (2000 to 2022).

Despite spatial variances, statistically in 2000 the minimum and maximum value of surface temperature record was 19.7°C and 37.2^{0}C respectively, in 2008 the minimum and maximum value of surface temperature record was 22.8°C and 32.9^{0}C respectively, and in 2022 the minimum and maximum value of surface temperature record was 30.2°C and 43.3^{0}C respectively.

From the analysis it is clear that the area having vegetation cover has relatively low LST due to the cooling effect of vegetation. While the built areas, bare land, and shrub land areas around has registered highest surface temperatures. This shows the impact of impervious surfaces on the elimination cooling effects. This is supported by the finding in which indicated the strong positive relationship of LST with NDBI. It is also consistent with several recent research findings , which state that natural land cover is rapidly being replaced by built-up areas, which contributing to the rise in LST. The Process of urbanization aggravates the LST intensity to significant levels, and also degraded the urban ecology and health of habitats (Arulbalaji et al., 2020). Rapid urbanization and industrialization increase the number of buildings, gases released from vehicles and industries (Manea et al., 2013), and non-evaporating impervious surfaces such as concrete and asphalt (Jianga and Tiana, 2010; Qijiao and Zhixiang, 2015; Tang et al., 2014), all of which directly heat the urban environment.

4.3.1. Land Surface Temperature Evaluation

The researcher attempted to evaluate the result of Landsat image-derived land surface temperature using MODIS 11 A2 data for the year 2022. In this study, the LST of 2022 in Dire Dawa was calculated using the Landsat 9 thermal band. As a result, the Landsat 9 thermal band (band 10) LST result is validated in this study using the MODIS 11A2 of 1 km spatial resolution acquired during the same time period. While the coarse resolution MODIS 11A2 based LST varied from 36^{o}C to 43^{o}C for the year 2022, the LST result retrieved from the thermal band (band 10) of Landsat 9 spans from 30^{o}C to 43^{o}C.

The LST variances obtained from the two thermal band sensors were similar across the research region. This suggests that the LST result for this study was most likely generated with high confidence. As shown in Figure (4.11), places dominated by vegetation cover, had low surface temperatures derived from both Landsat and MODIS. However, the majority of the city's western and northern areas, had high land surface temperatures derived from the thermal band of Landsat 9 and MODIS 11A2 data for the year 2022.

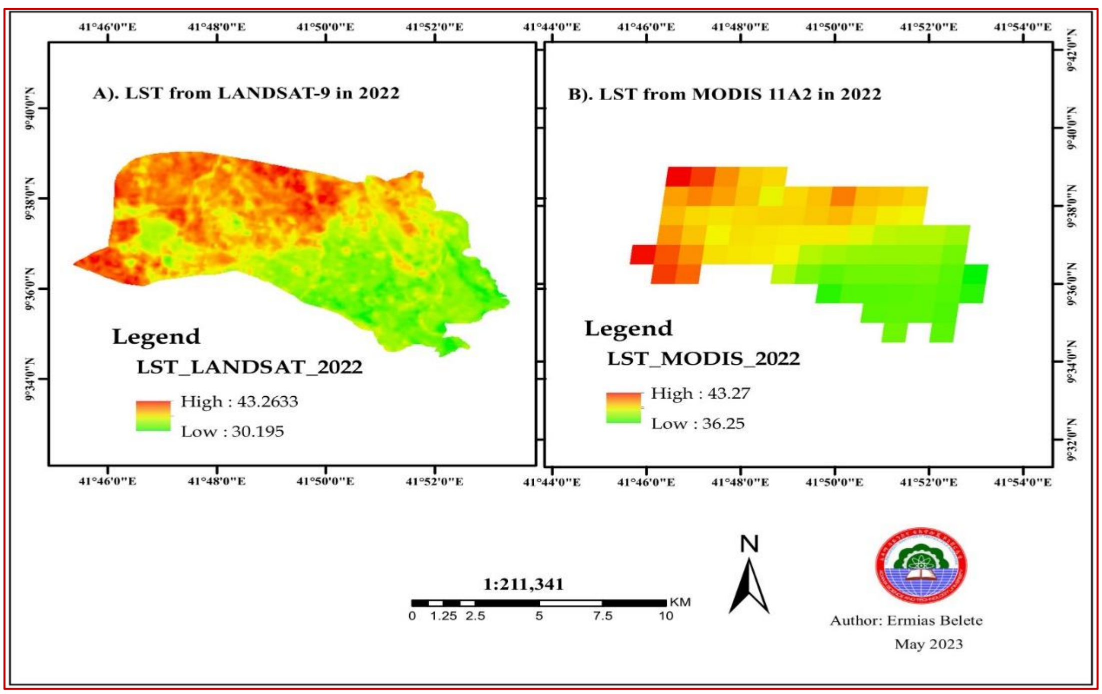


Figure 4.9: Evaluation of LST: Landsat 9 (left) by MODIS based LST (right) in Dire Dawa (2022).

4.4. Correlation of LST with Vegetation and Built-up Area

Maps extracted from near infrared and red-bands of the study periods indicated that different LULC has different NDVI values. As NDVI is related with the vegetation condition, the value varies from area to area based on vegetation intensity of the sites. To investigate the relationships between different LULC classes and LST, different types of land cover indices have developed. From the various indices, the researcher has found and select two major indices in the city. The Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-Up Index (NDBI) are two quantitative variables whose relationship is commonly investigated through the use of correlation and linear regression techniques. Correlation measures the strength of a linear relationship between two variables, whereas regression expresses the relationship mathematically (Bewick et. al., 2003).

To evaluate the thermal status of land surface by satellite, it is important to find the relation between LULC type and LST. Normalized difference vegetation index play a great role in assessing and investigating of ST. Surface temperature and NDVI have indirect relationships in different LULC categories. Vegetation condition (NDVI value) and types of LULC have impacts on LST value.

The results of the regression line of this study indicate that LST presents a positive correlation with NDBI (Figure 4.10) and negative correlations with NDVI (Figures 4.9). The coefficient of determination (R^2) values of 0.8874 in 2022 represent the link between the NDVI and LST, which indicate how the vegetation condition determine the LST of the area and NDVI accounts 88.74% in decreasing the distribution of LST. This demonstrated a considerable negative correlation or relationship between LST and the vegetation fraction (Figure 4.9). From the result the relationship between NDVI and LST had a negative relation meaning that, when the value of NDVI is increase, the amount of surface temperature is decrease. In this thesis the result shows that value of NDVI were decreased and the surface temperature increased see in (Fig 4.9) below. While the coefficient of determination (R^2) for the LST and NDBI is 0.9196, showing a strong positive link (Figure 4.10). The lowest mean land surface temperature corresponded to areas covered by vegetation, followed by other areas which are composed of the river side area. On other way, this means that the high value of LST corresponds to low surface water availability and vice versa.

Thus, as a result of the research, it was discovered that land surface temperature (LST) is sensitive to each land use type and may thus be used to identify changes in land use and land cover. Similarly sparse vegetation classes (forest, grassland, and wetland) have the lowest LST value whereas settlement; bare land, dry rivers, and farmland class have the maximum LST. Naim and Kafy (2021), also confirmed that, LST and built-up area have positive relationship, while LST have a negative correlation with vegetation.

The researcher stated that flora, in particular, plays a vital role in balancing local climates by regulating the temperature of the city's ground surface. This is due to the fact that vegetation can modify climate and weather patterns by releasing water vapor during photosynthesis. The emission of vapor into the atmosphere changes surface energy fluxes, which may result in the formation of clouds, which varies the amount of sunlight or radiation that can reach the Earth and impacts the energy balance of the planet.

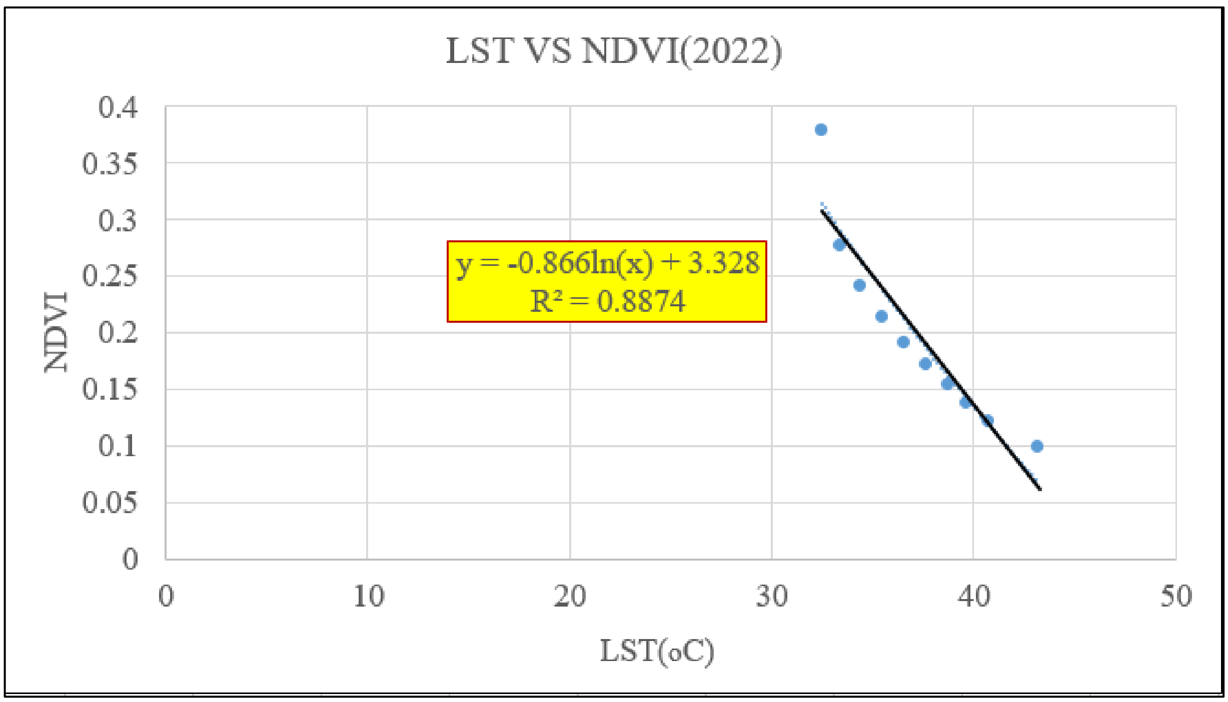


Figure 4.10: Correlation between LST and NDVI in Dire Dawa (2000 to 2022).

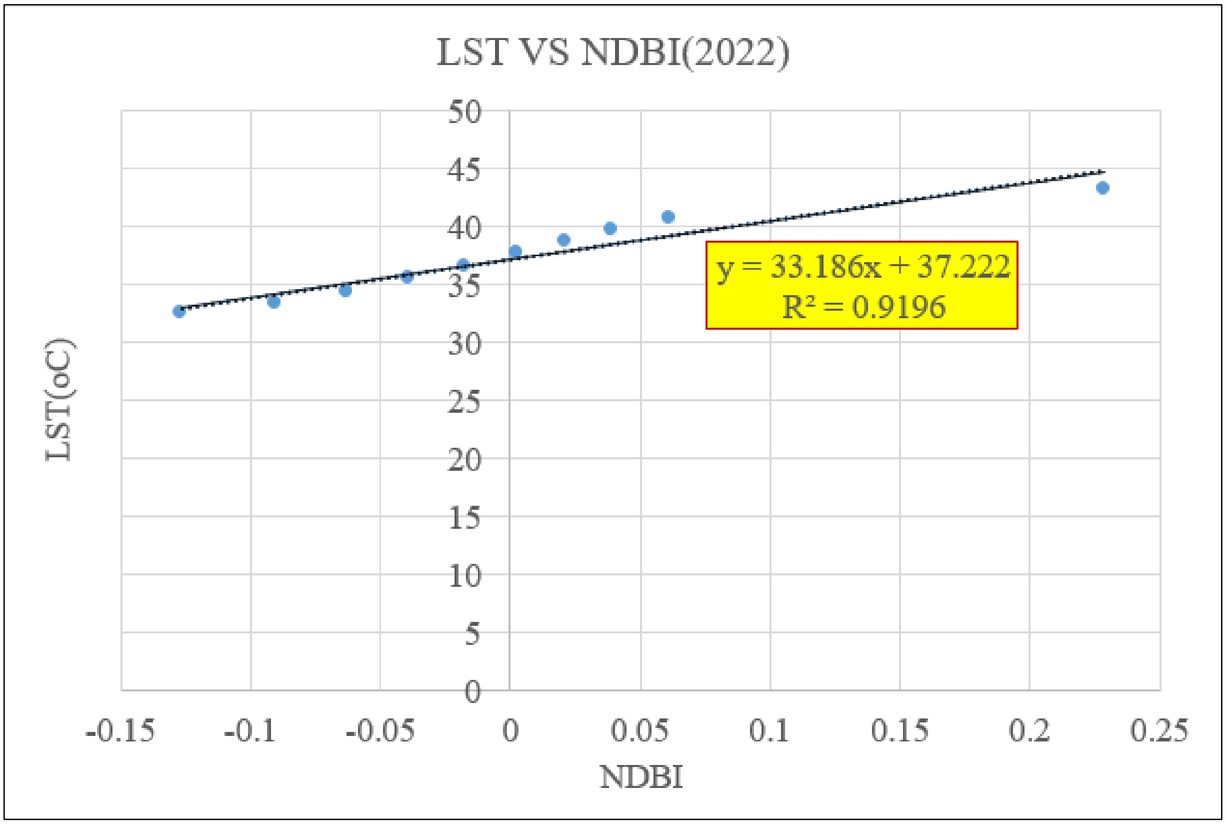


Figure 4.11: Correlation between LST and NDBI in Dire Dawa (2000 to 2022).

When examining the correlation of LST with vegetation and built-up areas, interesting patterns emerge. The implications of understanding the correlation of LST with vegetation and built-up areas are significant. Urban planners and policymakers can utilize this knowledge to inform decision-making processes for sustainable urban development. Overall, recognizing the correlation between LST, vegetation, and built-up areas empowers us to make informed choices about land use, urban planning, and the design of resilient and sustainable cities. By promoting the integration of vegetation and implementing measures to reduce heat retention in built-up areas, we can work towards creating more livable and environmentally friendly urban landscapes.

4.5. Thermal Comfort Level Assessment

The quality of urban health and ecology can be evaluated by how comfortable people feel in the environment in terms of its temperature. This is how UTFVI measures the level of thermal comfort. Figure (4.12) and Table (4.6) illustrate the threshold values of the UTFVI spatial and temporal distributions for the years 2000, 2008, and 2022. To better assess and evaluate the ecological thermal condition of the city, UTFVI is quantitatively analyzed following an equation used by many researchers (Naim and Kafy, 2021; Zhang et al., 2006). The UTFVI values were divided into six categories (Zhang, 2006) according to six different ecological evaluation indices (Table 3.3).

The visual interpretation of Figure (4.12) shows that the city was defined by two extreme categories of ecological or environmental evaluation standards. That is the list of the worst and excellent categories. The excellent ecological condition can be found in the southern, south-eastern, part of central areas, and riverside areas of Dire Dawa.

These areas of the city have a sparse of vegetation classes, whereas the majority of the city's northern and north-western areas were classified as having the worst ecological thermal conditions in 2000. Except for the south-eastern and riverside parts of the city, which still have excellent urban ecology, the rest of the city was exposed to the worst thermal conditions in 2022 after two decades. The majority of undeveloped land is either hills or designated as city parkland, Recreation Centre, Mountain, farm expansion, greeneries, and natural reserves have abundance of vegetation and resulted an excellent ecological evaluation index.

Concentrated urban development often leads to a degraded environment in built-up areas due to several reasons such as increased pollution levels, reduced green spaces, and a rise in temperature. However, in Dire Dawa city bare land and shrub land negatively impacted the environment. Firstly, bare land is susceptible to soil erosion, leading to nutrient loss and diminished soil fertility that impedes plant growth. Consequently, this can result in reduced productivity and biodiversity in the surrounding area. Secondly, shrub lands can also suffer degradation if not well-managed. Overgrazing by livestock can cause vegetation cover reduction and increase soil degradation, leading to further environmental issues. Additionally, invasive species can outcompete native plants, disrupting the natural balance of the ecosystem. Furthermore, poorly maintained bare land and shrub land may contribute to climate change.

Reduced vegetation cover results in decreased carbon dioxide uptake from the atmosphere, resulting in increased greenhouse gas emissions that exacerbate global warming.

It is important to prioritize the preservation and expansion of green spaces in urban areas not only in the central part of the city but throughout the study area in all directions. This will help to promote a healthier and more sustainable urban environment by providing natural habitats for wildlife, improving air and water quality, and reducing the urban heat island effect. Green spaces can also provide recreational opportunities for residents and visitors, and enhance the aesthetic appeal of the city. Therefore, the implementation of sustainable land management practices is crucial to prevent the degradation of bare land and shrub land, maintain a healthy ecosystem that supports biodiversity, and ensure climate stability.

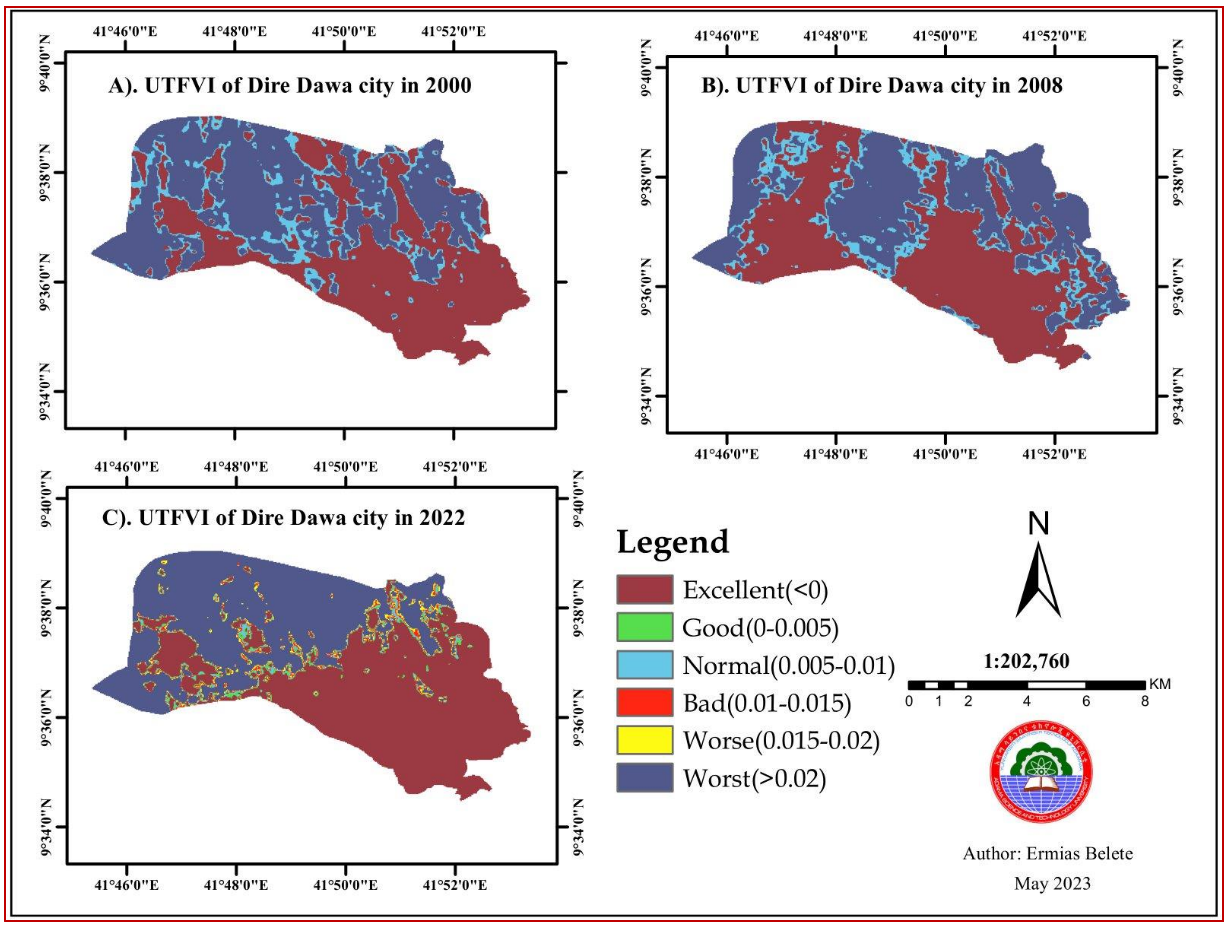


Figure 4.12: Spatial distribution of thermal ecology in Dire Dawa (2000 to 2022).

Table (4.6) and Figure (4.12) shows the statistical coverage of the thermal categories in Dire Dawa. It's apparent that the city endured two extreme orders of ecological evaluation excellent

(UTFVI< 0) and worst UTFVI>0.020) (Table 4.6 and Figure 4.12). Spatially, the excellent thermal conditions are substantially set up in southern, south-eastern, part of central areas and swash- side areas of the city. Still, the worst order (i.e., UTFVI>0.020) exists around the northern and north-western corridor of the study area characterized by bare land, and shrub land occupied by the worst conditions. This is due to the maturity of the land was impervious in nature i.e. bare land with an exposed gemstone face.

In 2000, 30.47km^2 and 30.67km^2 of the city area's geographical coverage fell into the excellent and worst categories, respectively. The area under excellent thermal conditions has increased over time in 2008 and now accounts for 33.96km^2, of the city's total area, in study's end year without any change from the prior year. On the contrary, the region that has been impacted by the worst UTFVI phenomenon increased to 29.39km^2 in 2022 from 26.49 km^2 in 2008 which shows progressive improvements negatively. The best thermal conditions for living are excellent zones with low UTFVI effects, whereas the worst zone represents a vulnerable environment prone to higher UHI phenomena.

Table 4.6: Statistical distribution of ecological evaluation index and thermal comfort area coverage in Dire Dawa (2000 to 2022).

EEI	**2000**		**2008**		**2022**	
	Area(km^2)	%	Area(km^2)	%	Area(km^2)	%
Excellent	30.4749	44.2%	33.9057	49.1%	33.9624	49.2%
Good					1.2663	1.8%
Normal	7.5231	10.9%	8.2728	12%	1.3419	1.9%
Bad					1.3761	2%
Worse					1.3374	1.9%
Worst	30.6738	44.5%	26.4933	38.4%	29.3877	42.6%
Total	69	100%	69	100%	69	100%

Where: EEI=Ecological Evaluation Index

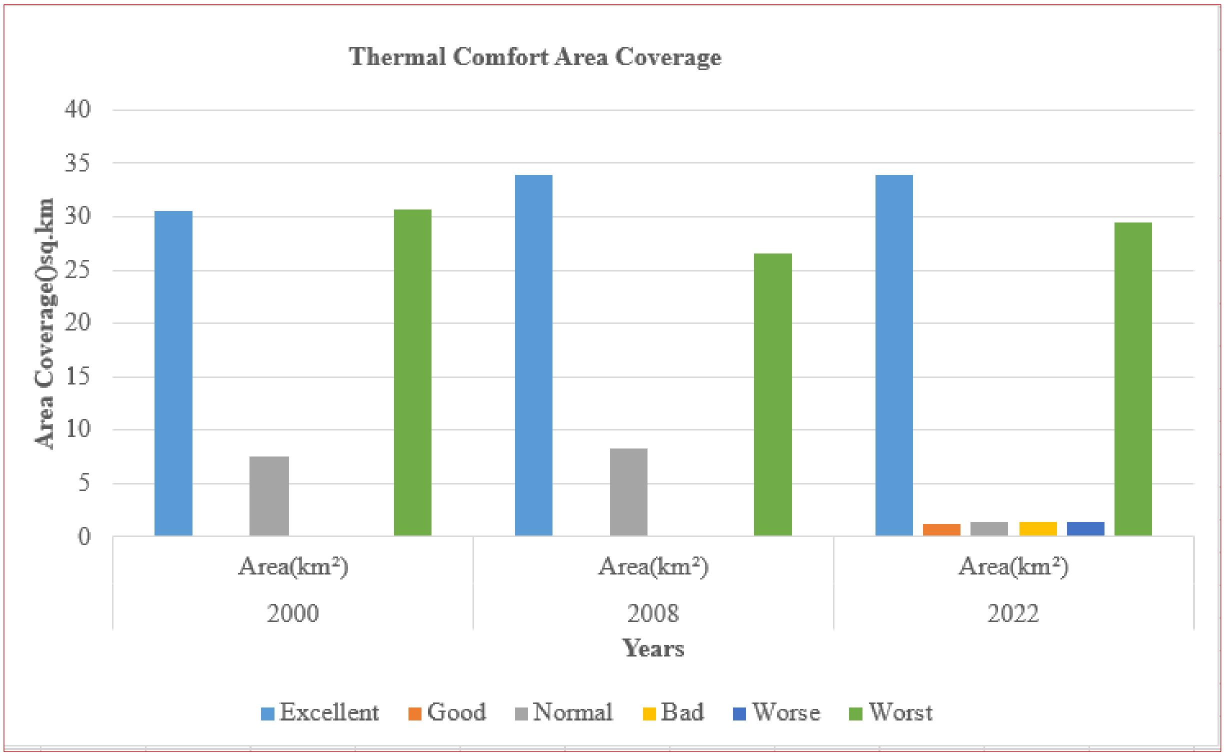


Figure 4.13: Thermal comfort areal coverage in Dire Dawa (2000 to 2022).

The data presented in table 4.6 and figure 4.12 illustrate how the city's thermal conditions have fluctuated over time. Furthermore, the trend shows that the area under the excellent category is continuing to remain constant, while the worst ecological zones have expanded significantly. The results of the seasonal UTFVI analysis highlight the city's gradual degradation of habitability. Thus, the researcher argued that, due to the expansion of individual's interest wise urbanization, there is an increase in discomfort in thermal condition in the city. Therefore, it is crucial to maintain this negative trend to ensure that the city's thermal conditions continue to improve. According to Choudhury et al. (2019), land surface temperature is rising at an alarming rate, and it has the potential to disrupt the ecology and habitat of a region. Rapid urbanization and unscientific developments have resulted in widespread environmental degradation (Arulbalaji et al., 2020).

4.6. Major Findings of The Study

The present study conducted on Study of the Impacts of Urbanization-induced Land Use Land Cover Changes on Land Surface Temperature and Thermal Comfort in Dire Dawa City Using Seasonal and Temporal Data over the Period 2000 to 2022 found the following major findings on the basic research questions:

❖ The Spatio-Temporal Status of LULC

The spatio-temporal status of Land Use and Land Cover (LULC) in the city indicates some significant changes. One prominent observation is the increasing transformation from shrub and bare land to built-up land use. This implies that urban development and constructions have been expanding, resulting in the conversion of natural vegetation into human-made structures and infrastructure.

On the other hand, the transformation of sparse vegetation covers into other land use categories has not been detected in the city. This suggests that areas with lower vegetation density, such as grasslands or sparsely vegetated regions, have remained relatively stable in terms of land use change. It could be due to limited urban development in these areas.

Additionally, the NDVI (Normalized Difference Vegetation Index) value of the city has shown a decreasing trend. NDVI is an indicator of the amount and health of vegetation cover in an area. The declining trend indicates a decrease in vegetation density within the city over time. This could be attributed to factors such as urbanization, land degradation, deforestation, or climate change impacts.

When comparing and contrasting these results with other, it is essential to consider various factors such as geographical context, urban planning strategies, environmental policies, and socio-economic conditions. The increasing transformation from shrub and bare land to built-up land use might be a common trend in rapidly developing urban areas globally.

Furthermore, the decreasing NDVI value indicates a potential environmental concern and highlights the need for sustainable land management practices. Comparing this trend with other cities may reveal similarities or differences in terms of vegetation decline, offering insights into regional or global environmental patterns. Such comparisons can help identify common challenges and potential solutions to mitigate the negative impacts of urbanization on vegetation and ecosystems.

In summary, the spatio-temporal analysis of LULC in the city reveals an increasing trend in the transformation from shrub and bare land to built-up land use, a stability in sparse vegetation covers, and a declining NDVI value. Further comparison and contrasting with other regions can provide valuable insights into the underlying causes and potential actions to address the observed changes in land use and vegetation dynamics.

- ✓ The transformation from shrub and bare land to built-up land use has been increasing.
- ✓ The transformation of sparse vegetation covers into other land use is not detected in the city.
- ✓ The NDVI value of the city has decreasing at the decreasing rate.

❖ The Spatio-Temporal Distribution of LST

According to the result of the study, the intensity of LST has predominantly increased in bare land, shrub land, and built-up land classes. This could be attributed to factors such as reduced vegetation cover, lower moisture content in the soil, and increased heat retention in developed areas. On the other hand, areas with vegetation cover tend to have relatively lower LST values due to the cooling effect of plants through evapotranspiration and shading of the ground surface.

It is mentioned that the LST result for this study was likely generated with high confidence, evaluated using MODIS (Moderate Resolution Imaging Spectroradiometer) data. MODIS is a satellite-based sensor that provides valuable information about various Earth surface parameters, including LST. Its high spatial and temporal resolution enables accurate monitoring and analysis of LST patterns over large areas.

To compare and contrast this result with other studies, it would be necessary to consider the specific methodologies, data sources, and study areas used in each research. Different studies may employ different sensors, such as Landsat or Sentinel satellites, which have varied characteristics compared to MODIS. Additionally, variations in the study regions, timeframes, and statistical methods used for analysis can lead to different findings.

It is important to gather information from multiple studies to have a comprehensive understanding of the spatio-temporal distribution of LST. By analyzing various research findings, scientists can identify consistent patterns and trends, as well as potential variations or discrepancies, which may be influenced by regional climatic conditions, land use changes, or other factors specific to each study location.

In conclusion, the findings of the study suggests that LST intensity has increased in bare land, shrub land, and built-up land classes, while areas with vegetation cover exhibit relatively lower LST values. The confidence of the LST result is evaluated using MODIS data, a reputable satellite-based sensor. Comparing and contrasting these findings with other studies requires consideration of various factors like data sources, study area, and methodologies employed.

- ✓ The intensity of LST has mostly increased in the land classes of bare land, shrub land, and built-up land classes.
- ✓ The area having vegetation cover has relatively low LST due to the cooling effect of vegetation.
- ✓ The LST result for this study was most likely generated with high confidence which is evaluated using MODIS data.

❖ The Correlation of LST and its responses to NDVI and NDBI

The results of the regression line in this study revealed that land surface temperature (LST) showed a positive correlation with normalized difference built-up index (NDBI) and negative correlations with normalized difference vegetation index (NDVI). This suggests that as the NDBI values increase, indicating a higher proportion of built-up areas, the LST also tends to increase. On the other hand, as the NDVI values increase, indicating greater vegetation cover, the LST tends to decrease.

It was also discovered that LST is sensitive to different land use types. The study found that the sparse vegetation class exhibited the lowest LST values, suggesting cooler surface temperatures. In contrast, the settlement and bare land classes displayed the highest LST values, indicating hotter surface temperatures. This indicates that land use plays a significant role in influencing surface temperatures.

Comparing these results to other studies, it is important to consider the specific geographic location and environmental factors involved. While the reported positive correlation between LST and NDBI aligns with previous research indicating that urban areas tend to have higher surface temperatures, the negative correlation between LST and NDVI may differ based on factors such as climate, soil moisture, and vegetation types.

It is worth noting that further research is needed to fully understand the complexities of this relationship between LST, NDVI, and NDBI. Additionally, studies in different regions with varying land use patterns and environmental conditions can provide a more comprehensive understanding of these correlations. These findings emphasize the importance of considering land use characteristics when analyzing land surface temperature and its relationship with vegetation and built-up areas. Overall, this study contributes to our understanding of the intricate dynamics between land surface temperature and land use, highlighting the need for continued research in this area.

- ✓ The results of the regression line of this study indicated that LST presented a positive correlation with NDBI and negative correlations with NDVI.
- ✓ It was discovered that land surface temperature (LST) is sensitive to each land use type.
- ✓ The sparse vegetation class has the lowest LST value whereas settlement and bare land classes have the maximum LST.

❖ The assessment of thermal comfort condition

The assessment of thermal comfort conditions in the city revealed two extreme ecological evaluations: the worst and excellent categories. An analysis of the trend indicates that the areas falling under the excellent category have been consistently maintaining their quality. On the other hand, the regions identified as the worst ecological zones have shown significant expansion over time.

This result suggests that the city has exhibited a mixed picture in terms of thermal comfort conditions. While some areas have managed to maintain an excellent level of comfort, others have experienced a deterioration in their ecological quality. The stability of the excellent zones may indicate effective urban planning strategies, such as the incorporation of green spaces, efficient building designs, or appropriate insulation measures.

However, the expansion of worst ecological zones raises concerns about various possible factors. These may include inadequate urban development planning, lack of green infrastructure, excessive land concreteization contributing to the urban heat island effect, or poor implementation of environmental regulations. It is essential to identify the specific reasons behind the expansion of these zones to develop targeted interventions for improvement.

To contextualize these findings, it would be valuable to compare and contrast them with data from other cities facing similar challenges. By examining and comparing various cities' approaches to thermal comfort assessment and ecological evaluations, valuable insights can be gained. This analysis can assist in identifying successful strategies implemented elsewhere that could be replicated or adapted to the present city's circumstances.

In conclusion, the assessment of thermal comfort conditions in the city demonstrates a contrasting situation between the excellent and worst ecological zones. The stability of the excellent areas indicates effective planning, while the expansion of worst ecological zones raises concerns. By comparing and contrasting these findings with other, valuable lessons can be learned to develop targeted interventions and improve the overall ecological quality and thermal comfort conditions in the city.

- ✓ The city was defined by two extreme ecological evaluation i.e. the worst and excellent.
- ✓ The trend shows that the area under the excellent category is continuing to remain constant, while the worst ecological zones have expanded significantly.

CHAPTER V: CONCLUSION AND RECOMMENDATION

This chapter deals with three important issues. The first part, presents the conclusions that were reached from the findings as per the objectives the study tried to address. In the second part the researcher's recommendations that were inferred from the findings and conclusion were presented. In the final part the researcher suggested a few points for future studies that experienced, faced challenges and limitations during the span of the study.

5.1. Conclusion

This section concluded the study by summarizing the key research findings in relation to the research aims and research questions, as well as the value and contribution thereof. In this study, remotely sensed satellite data (Landsat 5 TM, and Landsat 9 OLI/TIRS), MODIS data, and observational data were manipulated and have played a significant role in the accomplishment of this study. The results of the study have been analyzed from the perspective of Land use land cover change (spatio-temporally), Vegetation fraction, Land surface temperature (spatio-temporal), Correlation (LST and NDBI, LST and NDVI), and the status of thermal variance of the city. For the purpose of analysis, ERDAS IMAGINE, ArcGIS, Excel, and ENVI software were becoming critical for the analysis.

The study analyzed the spatio-temporal pattern of land use land cover in Dire Dawa city for two decades using Landsat images from 2000, 2008, and 2022. The study area has experienced significant changes in land use and land cover between 2000 and 2022. The results showed that urban settlement increasing at an alarming rate. During the course of 22 years, there was a noteworthy rise in developed land while other land classifications saw a decline. Barren land and shrub land showed continuous decrement, whereas sparse vegetation remained constant with a little increment. The built-up area expanded significantly, gaining about $10km^2$ land from bare land and shrub land cover categories. The transformation from shrub and bare land to built-up land use has been increasing, led to a decrease in other land categories, affecting the city's ecology. Protecting forest areas and planting additional trees including urban gardening, parks, and greenery areas are crucial to maintaining the city's ecological balance. The study highlights the importance of sustainable urban development that balances economic growth with environmental sustainability and biodiversity conservation.

The study area of Dire Dawa has experienced changes in the spatial distribution of LST over the two-decade study period. The intensity of LST has mostly increased in the land classes of bare land, shrub land, and built-up land class, which can be attributed to the reduction in vegetation cover and increased impervious surfaces. These changes have resulted in an increase in surface temperature record, especially in areas with industrial, and mining activities that release gases and have non-evaporating impervious surfaces of bare land. The study findings highlight the need for urban planning and management strategies that take into account the impact of land use and land cover changes on LST and the urban ecology and health of habitats.

The investigation has conclusively established a significant correlation between land use and land cover (LULC) and land surface temperature (LST). In order to meticulously examine this association, the researcher has pinpointed two primary indicators, specifically, the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI). The results have revealed that NDVI exhibits a negative correlation with LST, indicating that an enhancement in vegetation condition (NDVI value) leads to a decrease in LST. Conversely, NDBI has demonstrated a positive correlation with LST, implying that an amplification in the built-up area results in an increase in LST. It has been noted that those areas which present themselves with sparse vegetation, such as woodlands, pastures, and marshes, exhibit the most minimal Land Surface Temperature (LST) values. Conversely, areas of human habitation, barren territories, arid watercourses, and agricultural fields demonstrate the highest LST values. In conclusion, the study highlights the importance of vegetation in regulating the temperature of the ground surface.

Furthermore, the assessment of thermal comfort and its statistical analysis in Dire Dawa revealed that the land area of the city was changed to the worst category. Moreover, the city has experienced stressful thermal ecology in the northern and north-western parts as the finding revealed that. The use of the Urban Thermal Comfort Index (UTFVI) has enabled the city to evaluate the level of thermal comfort experienced by its residents. The researcher believes this work can contribute to the urban environment sustainability field of study by opening ways for multidivisional decision making and multidisciplinary planning approaches.

5.2. Recommendation

Based on the study's findings and conclusions, Land Use Land Cover Change (LULCC) have significant impacts on Land Surface Temperature (LST) and Thermal Comfort. Here are a few recommendations made by researcher for those impacts to enhance urban sustainability and minimize thermal effect in the case of Dire Dawa city.

1. Urban Development and Construction: In light of the researcher's argument about the negative impact of uncontrolled horizontal expansion on controlling urban ecology, it is essential to take measures to ensure sustainable development. Built-up land was aggressively expanded in Dire Dawa at the expense of other land use land cover features. Although a plethora of justifications are enumerated, the main one was the desire to find a low-cost land for home. As a result, the urban development and construction office of Dire Dawa City, along with other private and governmental organizations, should take actions such as the construction of housing projects that provide opportunities for people of all socioeconomic backgrounds and are affordable and accessible in order to reverse the unplanned expansion of urban coverage.

2. Increase Green Spaces: Based on the decreasing trend of NDVI in the city from 2000 to 2022, it is recommended to adopt measures to increase the green cover in the city. This can be achieved by planting trees and other vegetation in open spaces and along roadsides. Green legacy advocacy which is initiated by the Prime Minister Abiy Ahmed (Dr.) should be transformed into policies by setting guidelines through an inclusive approach to reduce and adjust the thermal stress of the city by increasing the vegetation fraction and decrease energy needed for cooling. As far as the impact of surface temperature can be controlled using the plantation of trees, it is advisable to participate the community actively.

Therefore, the city administration should invest in planting trees which are mostly used as food sources, such as mango, papaya, oranges, and others, in which the community and the city as a whole can benefit both as a source of food and to control the degradation of the environment. Furthermore, this could help to supply fresh fruits at a low cost while also reducing unemployment and living costs for the urban population.

3. **Preservation of Natural Areas:** Based on the findings of the research, it is recommended that city planners and policymakers prioritize the preservation and incorporation of green spaces and vegetation in urban development. Achieving this objective is possible through the employment of sustainable land-use practices, specifically those that entail reforestation and afforestation. Also, there should be strict regulations guiding the conversion of natural land covers into built-up areas, with measures in place to mitigate the impact of impervious surfaces on the elimination of cooling effects. This would help to reduce the intensity of LST and improve the overall urban ecology and health of habitats. Finally, there should be sustained public awareness campaigns to educate people on the importance of preserving natural land covers in their communities.

4. Urban Planning: Developing urban areas with consideration for LST and thermal comfort can lead to more comfortable and livable cities. Planning new buildings and infrastructure to create shaded areas and cooling breezes can help to decrease temperatures and improve thermal comfort. Decreasing the impact of urban heat islands through green roof technology, lighter-colored surfaces, and other mitigation measures can help to cool urban areas and improve thermal comfort.

5. Collaboration: The city's environment office should collaborate closely with higher education institutions (universities) to conduct continuous assessments or evaluation of the city's surface temperature in order to take necessary corrective actions.

6. Ecotourism: Promoting the local economy by putting a strong emphasis on service industries such as parks, and other tourism industries. This can relieve pressure on vegetation and help to restore ecology by controlling the surface temperature. As a result, I recommended that the city's investment bureau, as well as federal authorities, prioritize biodiversity and sustainability when making investments permissions.

7. Based on the similarity of the LST variances obtained from the Landsat and MODIS thermal band sensors, it can be recommended that either of these sensors can be used to generate reliable LST results for the study region. It may be useful to evaluate the performance of both sensors on a larger sample of the study area and validate the results through other reliable sources. Additionally, it may be beneficial to explore the potential of combining data from both sensors to obtain a more comprehensive understanding of the LST dynamics in the research region.

8. According to the research findings, it is advised that the municipality should initiate measures to enhance its thermal environment. The city should also monitor the trend of the thermal categories periodically and make necessary adjustments to its policies and practices accordingly.

5.3. Suggestions for Future Studies

The researcher provided the following suggestions for future researchers on the topic and on the research so that a more accurate result can be achieved.

For forthcoming scholars, it is highly advised to concentrate on particular facets of the influence of urbanization-induced land use land cover changes on land surface temperature and thermal comfort in Dire Dawa city, rather than trying to cover multiple points and issues in a single study. This will help in achieving more accurate and specific results.

Additionally, future researchers can explore the effectiveness of different mitigation measures to reduce the negative impacts of urbanization on land surface temperature and thermal comfort in the city. They can also conduct comparative studies of the impacts of urbanization on different cities or regions with varying levels of urbanization and land use changes.

It is recommended to amass data for an extended duration to gain a more comprehensive comprehension of the enduring influences of urbanization on land surface temperature and thermal comfort. Furthermore, it would be beneficial to integrate qualitative research methodologies, including interviews, surveys, and focus groups, to obtain a more profound understanding of the experiences and perceptions of the residents of Dire Dawa city regarding urbanization-induced land use land cover changes.

Finally, future researchers can consider taking into account the impacts of climate change, as it is likely to exacerbate the effects of urbanization on land surface temperature and thermal comfort. In order to attain a more extensive and precise comprehension of the effects of urbanization on the environment and human well-being, it is imperative to focus on these specific domains in upcoming research endeavors.

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APPENDIXES

APPENDIX A: Land surface Temperature Measurement Calculation for Landsat 5.

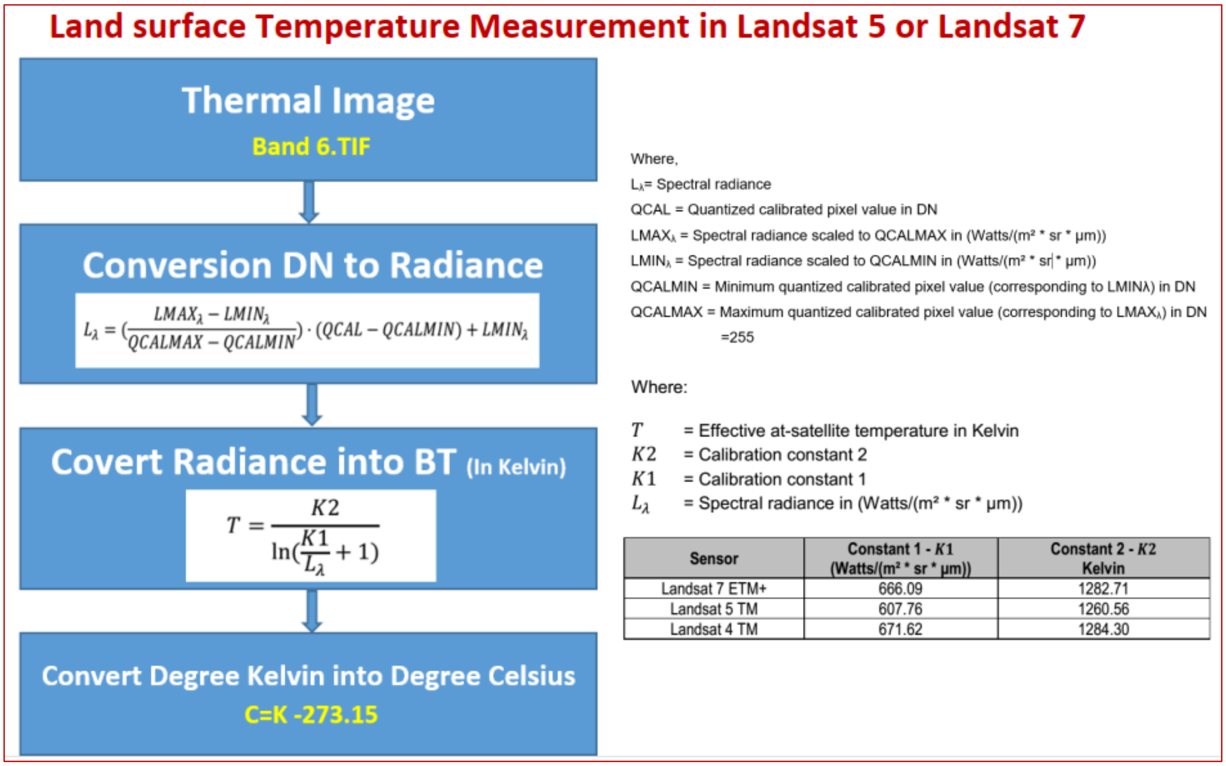

Figure 4.14: Land surface Temperature Measurement algorithm for Landsat 5.

APPENDIX B: Land surface Temperature Measurement Calculation for Landsat 9.

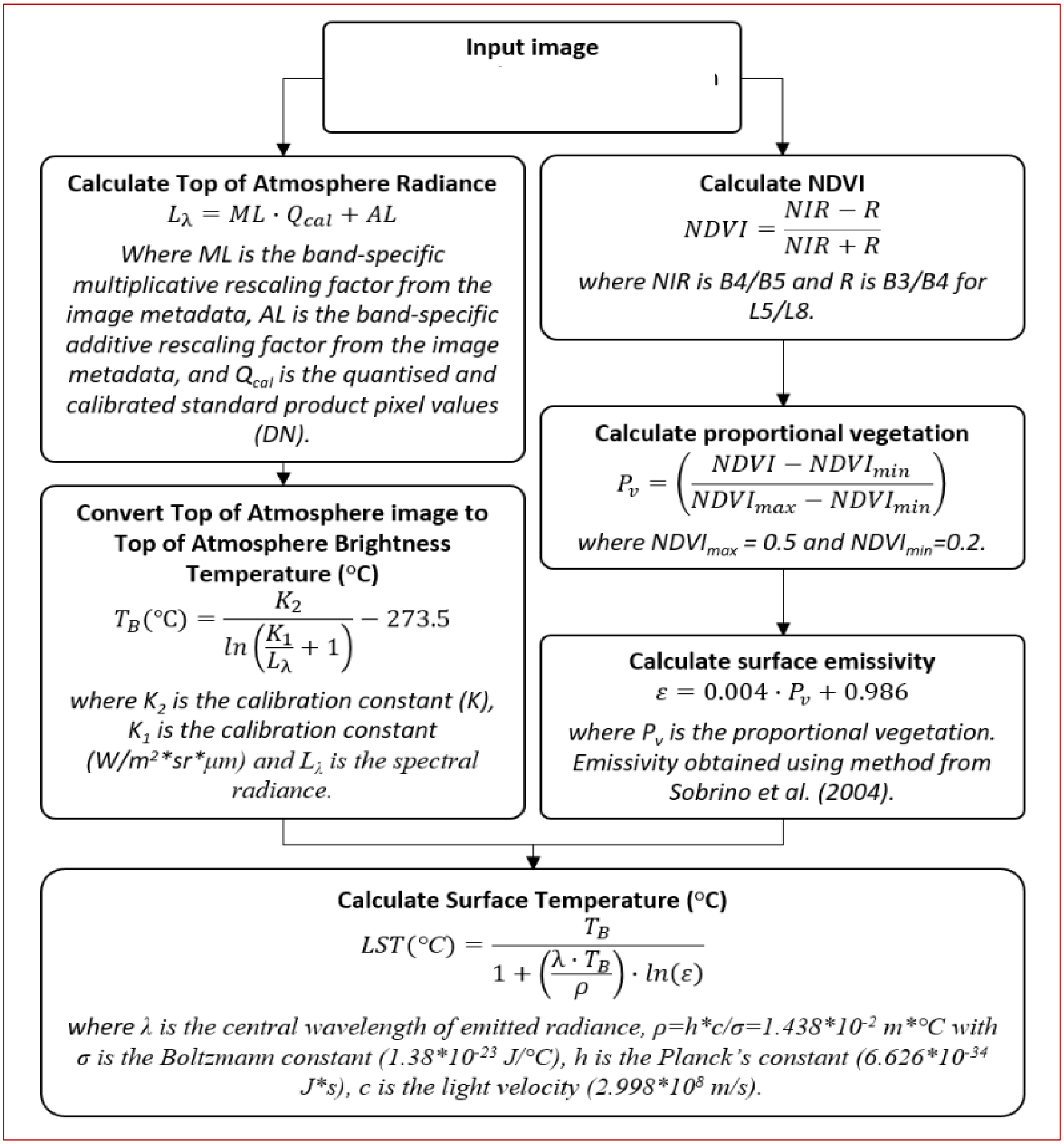

Figure 4.15: Land surface Temperature Measurement algorithm for Landsat 9.

APPENDIX C: Sample Points for Accuracy Assessment

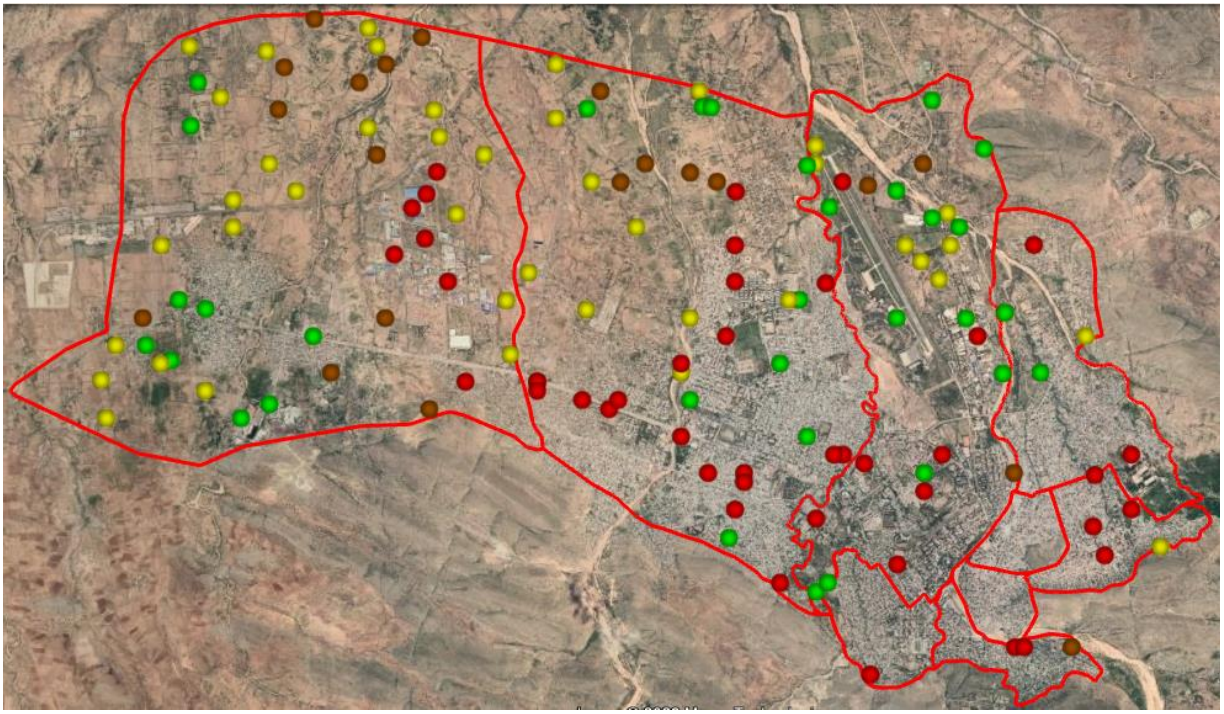

Figure 4.16: Distribution of sample points for accuracy assessment of LULC map of Dire Dawa (2022).

APPENDIX D: NDBI Computation Algorithm.

Table 4.7: NDBI Computation Algorithm.

Ref. No	Index used	Equation
[6]	NDII	$\frac{VIS - TIR1}{VIS + TIR1}$
[9]	NDBI	$\frac{SWIR1 - NIR}{SWIR1 + NIR}$
[5]	NDISI	$\frac{TIR1 - [\frac{WI + NIR + SWIR1}{3}]}{TIR1 + [\frac{WI + NIR + SWIR1}{3}]}$
[13]	MNDWI	$\frac{Green - SWIR1}{Green + SWIR1}$

APPENDIX E: Accuracy Assessment Matrix

Table 4.8: Shows the user defined and reference matrix accuracy assessment of land use land cover map of the study.

ID	User	Ref	ID2	User3	Ref4	ID5	User6	Ref7	ID8	User9	Ref10	ID11	User12	Ref13
ID#1	BA	BA	ID#23	SL	SL	ID#45	BA	BA	ID#67	SL	BL	ID#89	SL	SL
ID#2	BA	BA	ID#24	BA	BL	ID#46	SV	SV	ID#68	BA	BA	ID#90	BA	BA
ID#3	BA	BA	ID#25	SV	SV	ID#47	BA	BA	ID#69	BA	BA	ID#91	BA	BA
ID#4	BA	BA	ID#26	SV	SV	ID#48	BA	BA	ID#70	BA	BA	ID#92	BA	BL
ID#5	BA	BA	ID#27	BA	BA	ID#49	BA	BA	ID#71	BA	BA	ID#93	BA	BA
ID#6	BA	BA	ID#28	BA	BA	ID#50	BA	BA	ID#72	BL	BL	ID#94	BA	BA
ID#7	SL	SL	ID#29	BA	BA	ID#51	BA	BA	ID#73	BA	SV	ID#95	BA	BA
ID#8	BA	BA	ID#30	BA	BA	ID#52	BA	BA	ID#74	BA	SV	ID#96	SV	SV
ID#9	BA	BA	ID#31	BA	BA	ID#53	BA	BA	ID#75	BA	BA	ID#97	SV	BA
ID#10	BA	BA	ID#32	BA	BA	ID#54	BA	BA	ID#76	SL	SL	ID#98	BA	BA
ID#11	BA	BA	ID#33	SL	SL	ID#55	SL	SL	ID#77	BA	BA	ID#99	BA	BA
ID#12	BA	BA	ID#34	BA	BA	ID#56	BA	BA	ID#78	BA	BA	ID#100	BA	BA
ID#13	BA	BA	ID#35	BA	SL	ID#57	BA	BA	ID#79	BA	BA	ID#101	SL	SL
ID#14	BA	BA	ID#36	BA	BA	ID#58	BA	BA	ID#80	BA	BA	ID#102	BA	BA
ID#15	BA	BA	ID#37	BA	BA	ID#59	SL	SL	ID#81	BA	BA	ID#103	BA	BA
ID#16	BA	BA	ID#38	SL	BA	ID#60	BA	BA	ID#82	BA	BA	ID#104	SL	SL
ID#17	BA	BA	ID#39	BA	BA	ID#61	SL	SV	ID#83	BA	BA	ID#105	BA	BA
ID#18	SL	SL	ID#40	BA	BA	ID#62	BL	BA	ID#84	SL	SL	ID#106	BA	BA
ID#19	BA	BA	ID#41	BL	BL	ID#63	BA	SL	ID#85	BA	BA	ID#107	BA	BA
ID#20	BA	BA	ID#42	SV	SV	ID#64	BA	BA	ID#86	BA	BA	ID#108	BA	BA
ID#21	BA	BA	ID#43	SV	SV	ID#65	SV	SV	ID#87	BA	BA	ID#109	BA	BA
ID#22	BL	BAL	ID#44	BA	BA	ID#66	BA	BA	ID#88	BA	BA	ID#110	BA	SV

ID	User	Ref	ID2	User3	Ref4	ID5	User6	Ref7	ID8	User9	Ref10	ID11	User12	Ref13
ID#111	BA	BA	ID#133	BA	BA	ID#155	BA	SV	ID#177	SV	SV	ID#199	BA	BA
ID#112	BL	BL	ID#134	SL	SL	ID#156	BA	SV	ID#178	BA	BA	ID#200	SL	SL
ID#113	BA	BA	ID#135	BA	BA	ID#157	BA	SV	ID#179	SL	SL	ID#201	BA	BA
ID#114	BA	BA	ID#136	BA	BA	ID#158	SL	BL	ID#180	SL	SL	ID#202	BA	SV
ID#115	BA	BA	ID#137	BA	BA	ID#159	SL	SL	ID#181	SV	SV	ID#203	SL	SV
ID#116	BA	BA	ID#138	BA	BA	ID#160	BA	BA	ID#182	BA	BA	ID#204	SV	SV
ID#117	BL	BL	ID#139	BA	BA	ID#161	BA	BA	ID#183	SV	SV	ID#205	BA	BL
ID#118	BA	BA	ID#140	BA	BA	ID#162	BA	BA	ID#184	SV	SV	ID#206	BA	BA
ID#119	BA	BL	ID#141	BA	BA	ID#163	BA	BA	ID#185	BA	SV	ID#207	SL	BA
ID#120	BA	SL	ID#142	BA	BA	ID#164	BA	BA	ID#186	BA	BA	ID#208	BA	BA
ID#121	BA	BA	ID#143	BA	BA	ID#165	BA	SL	ID#187	BA	BA	ID#209	BA	BA
ID#122	SV	SV	ID#144	BA	BA	ID#166	BA	BA	ID#188	BA	BA	ID#210	SV	SV
ID#123	BL	BL	ID#145	BA	BA	ID#167	BA	BL	ID#189	BA	BA	ID#211	BA	BA
ID#124	BA	BA	ID#146	BA	BA	ID#168	BA	SL	ID#190	SL	SL	ID#212	BA	BA
ID#125	BA	BA	ID#147	BA	BA	ID#169	BL	BL	ID#191	BA	BA	ID#213	BA	BA
ID#126	BA	BA	ID#148	BA	BA	ID#170	BA	BA	ID#192	SL	SL	ID#214	BA	BA
ID#127	SL	SL	ID#149	SL	SL	ID#171	BA	BA	ID#193	SL	SL	ID#215	BA	BA
ID#128	SL	SL	ID#150	SL	SL	ID#172	SL	BA	ID#194	SL	SL	ID#216	BA	BA
ID#129	SL	SL	ID#151	BA	BA	ID#173	BA	BA	ID#195	BA	BA	ID#217	SL	SL
ID#130	BA	BL	ID#152	BA	BA	ID#174	SL	BL	ID#196	BA	BA	ID#218	BA	BA
ID#131	BA	BA	ID#153	BA	BA	ID#175	SL	SL	ID#197	BA	BA	ID#219	BA	SL
ID#132	BA	BA	ID#154	SL	SL	ID#176	BA	BA	ID#198	SL	SL	ID#220	BA	SV

ID	User	Ref	ID2	User3	Ref4
ID#221	BA	BA	ID#243	BL	BL
ID#222	BA	BA	ID#244	BL	SL
ID#223	BA	BA	ID#245	SV	SL
ID#224	BA	SV	ID#246	SV	SV
ID#225	BA	BA	ID#247	SL	SV
ID#226	SL	SL	ID#248	BL	BL
ID#227	BA	BA	ID#249	SL	SL
ID#228	BA	SV	ID#250	SL	BL
ID#229	BA	BA	ID#251	SL	SL
ID#230	BL	BL	ID#252	SL	SL
ID#231	BL	SV	ID#253	SL	SL
ID#232	BA	BA	ID#254	SL	SL
ID#233	BA	BA	ID#255	SL	SL
ID#234	BA	BA	ID#256	SL	SL
ID#235	SL	BA			
ID#236	SV	SV			
ID#237	SV	SV			
ID#238	BL	BL			
ID#239	SV	SV			
ID#240	SL	SL			
ID#241	BL	BL			
ID#242	SL	SL			

Where; ID= feature ID, Ref= reference source, User=assigned class values

BA= Built-up Area, BL= Barren Land, SV=Sparse Vegetation, SL=Shrub Land.