People’s Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University of Mohamed BOUDIAF M’sila

Urban Techniques Management Institute
Department of City Management

Dissertation submitted in Partial Fulfillment of the Requirements for Master’s Degree in City Management
Specialty: City Management
Title of Master's Dissertation:

Urban Heat Island Risk Assessment And Hazard Mitigation Study Of M’sila City

Defended by:
Oudina Chourouk Nor El Ain

Examiners:
Chairperson: Taibaoui Saad
Examiner: Dechaicha Assoule

Supervised by:
Dr. Ouzir Malika

Co-supervisor:
Slimani Nabil

Academic Year: 2024/2025

Acknowledgements

"My Lord, enable me to be grateful for Your favor which You have bestowed upon me and upon my parents, and to do righteousness of which You approve and admit me by Your mercy among Your righteous servants."

First and foremost, I extend my deepest thanks to Allah Almighty, who illuminated our path with knowledge and wisdom, and granted me the strength and guidance to complete this work successfully.

I would like to express my deepest gratitude to **Dr. Ouzir Malika** for her exceptional guidance, generous availability, unwavering support, and invaluable contributions throughout the course of this work. It's profound expertise, insightful feedback, and continuous encouragement have been instrumental in shaping the direction and quality of this research.

I would also like to extend a thank to **Nabil Slimani** for his guidance that's help me throughout the preparation and of this thesis.

إهداء

"وَآخِرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ"

الحمد لله شكرا وحبا وامتنانا على البدء والختام

ما سلكنا البدايات إلا بتيسيره وما بلغنا النهايات إلا بتوفيقه وما حققنا الغايات إلا بفضله، فالحمد لله الذي وفقني لتثمين هذه الخطوة في مسيرتي الدراسية.

أهدي تخرجي بكل فخر إلى نفسي الطموحة جدا التي لم تخذلني يوما رغم قساوة الرحلة

وبكل حب أهدي ثمرة نجاحي:

إلى الراحلة من حياتي الحاضرة في قلبي دائما، إلى فقيدة روحي التي لطالما تمنيت أن تقرّ عينها برؤيتي في يوم كهذا لكنها غادرتني مبكرا " أمي رحمها الله ".

إلى من كلله الله بالوقار والهيبة، إلى من لا ينفصل اسمه عن اسمي، الذي دعمني بلا حدود وأعطاني بلا مقابل، مصدر قوتي وضلعي الثابت " أبي الغالي "

إلى من ساندتني عند ضعفي ولطالما ضمت اسمي بدعواتها لتحيطني وتسند روحي، إلى من أنارت باللّطف والوُد طريقي " غاليتي زهيرة "

إلى من شدّ الله بهم عضدي فكانوا خير معين، أمان قلبي الذين انتظروا هذه اللحظة ليفتخروا كما افتخر بهم " إخوتي وأخواتي "

إلى من جادوا عليّ بأوقاتهم وكرمهم ولطفهم، جنود الخفاء الذين آمنوا بقدراتي وراهنوا على نجاحي " أحباب المواقف لا السنين "

إلى كل من لم يتسع المقام لذكرهم وكل من استحضرته أو لم تستحضره الذاكرة في هذه اللحظات.

Dedication

"وَآخِرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ "

Praise be to God, thanks, love and gratitude for the beginning and conclusion.

We did not reach the beginnings except with His facilitation, we did not reach the ends except with His success, and we did not achieve the goals except by His grace. Praise be to God who enabled me to value this step in my academic career.

I proudly dedicate my graduation to my very ambitious self, which has never let me down despite the harshness of the journey

With all my love, I dedicate my graduation and success:

To the one who departed from my life but remains forever present in my heart, to the soul I dearly miss and always wished could witness this day **" my mother, may Allah have mercy on her"**

To the one whom Allah has adorned with dignity and honor, to the one whose name is inseparable from mine, who supported me without limits and gave without expecting anything in return **" my beloved father, my source of strength and unwavering pillar"**

To the one who stood by me in my moments of weakness, who always wrapped my name in her prayers to protect me and uplift my spirit, to the one who lit my path with kindness and affection **" my dear Zahira "**

To those whom Allah strengthened me with, who were a great support and a source of comfort for my heart, who awaited this moment to be proud, just as I am proud of them **" my brothers and sisters"**

To those who generously gave me their time, kindness, and generosity, the unsung heroes who believed in my abilities and bet on my success **″ the friends of moments, not of years"**

To all those whose names I could not mention, and to everyone my memory recalls or fails to recall at this moment.

Abstract

In the twenty-first century, urban heat island (UHI) has become a major problem for humanity. It is a kind of heat accumulation phenomenon within urban area due to urban construction and human activities. It is recognized as the most evident characteristic of urban climate.

The primary objective of this thesis is to delve into the concept of Urban Heat Island and contextualizes the phenomenon within a historical framework to highlight and summarize significant findings on the UHI phenomenon and its consequences.

The aim of this dissertation is to analyze the causes and consequences of the UHI focusing on a case study of the city of M’sila. In addition, the most common effective strategies and tools that could be applied in mitigating rising temperatures in urban areas were reviewed and summarized. In general, green areas in cities are thought to be an effective approach to mitigate urban heat island effects and bring comfort to residents.

The analysis is based on land cover & use (LC) classification (urban, green, and bare areas). The study found that bare areas had the highest mean LST values compared to the urban and green areas.

TABLE OF CONTENT

General Introduction

Comprehensive and Literature Review

Presentation of M'sila City

Case Study

LIST OF FIGURES

LIST OF TABLES

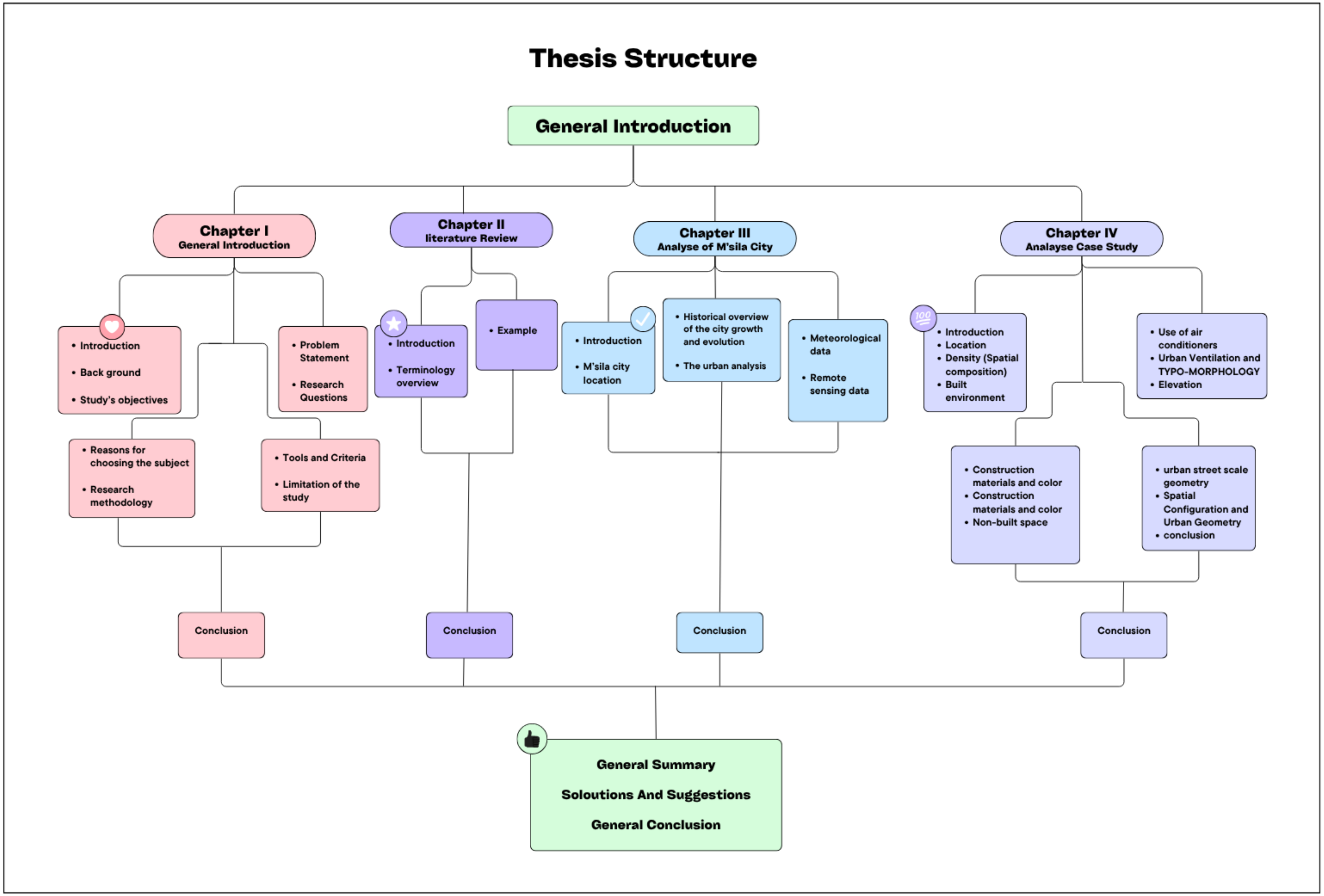


Figure 01: Thesis structure **(By the student)**

The Theoretical Part

I. Introduction

In recent decades, rapid urbanization and industrial development have significantly altered the natural landscape, giving rise to a phenomenon known as the Urban Heat Island (UHI) effect. This term refers to the noticeable temperature difference between urban areas and their surrounding rural environments, primarily caused by the concentration of buildings, roads, and other infrastructure that absorb and retain heat. As global temperatures continue to rise due to climate change, understanding and addressing UHI has become increasingly important for ensuring environmental sustainability, public health, and urban livability.

The primary aim of this research project is to develop a comprehensive and in-depth understanding of the phenomenon of UHI, by examining its underlying causes, spatial manifestations, and broader environmental and societal implications. This topic touch in the same time urban planning, climate change and bioclimatic design.

Furthermore, in its scientific framework, this research seeks to identify practical methods and solutions that can be implemented to mitigate and combat its effect, contributing to the development of more sustainable and resilient cities.

This research through its four parts: general introduction, literary review, analyze of the city of M’sila and the case study (the analysis of the neighborhood) seeks to understand the main causes and results of Urban Heat Island by examining the UHI phenomenon through its multiple dimensions and implications, this research will be grounded in an empirical case study conducted within a carefully selected urban area. The selection of this area is informed by an analysis of Land Surface Temperature (LST) data, which reveals that the identified neighborhood lies within a zone characterized by relatively elevated surface temperatures. This spatial indicator highlights the neighborhood's vulnerability to the Urban Heat Island effect, this making it a representative and relevant site for in-depth investigation.

I. Back Ground

In this decade, urbanization has been the most influential anthropogenic activities. The rapid increase in population and people movement from green areas to crowded areas result in urban and suburban environmental instability. (Muhammad , et al., 2023).

Rapid urban sprawl typically results in the conversion of open spaces, such as natural land cover consisting of soil and vegetation, into artificial surfaces, which consist of concrete, asphalt, and other impervious surfaces. This process inevitably results in changes in the absorption and reflection of solar radiation and the balance of surface energy. It also results in contrast changes to the urban-surroundings/urban–rural environment, in terms of surface radiance and air temperature. This difference in ambient air temperature between the urban-surroundings/urban–rural areas result in a phenomenon known as Urban Heat Islands (UHI). (Abulibdeh, 2021)

Urban heat island (UHI) is an urban climate phenomenon that primarily responds to urban conditions and land use change. The extent of hard surfaces significantly influences the thermal properties of the land. To address this issue, a novel approach quantifying the association between land use and UHI is developed.

An improved understanding of the relationships between UHIs and urban expansion is essential for urban ecosystem studies and urban planning and management. (Lili , et al., 2016)

The relationship between land use type and the UHI effect has recently been thoroughly investigated. The alteration of land uses is an important driver of intensive migration and urbanization, resulting in the change of landscape properties and also influencing the conversion of energies from the surface to the atmosphere. (G, HA, & A, 2020)

UHI is primarily caused by a larger proportion of man-made impermeable surfaces and a lower proportion of natural land cover. The replacement of natural land covers like a plant, soil, and water with artificial impermeable surfaces like asphalt, concrete, and metal has severe environmental consequences, including reduced evapotranspiration, increased storage and transmission of sensible heat, and decreased air circulation. (Fadhil, Hamoodi, & Ziboon, 2025)

In cities, increased industrialization and urbanization have resulted in significant pollution concerns. Sulphur dioxide, particulate matter, nitrogen oxides, carbon monoxide, and other pollutants have a direct impact on human health as well as historical monuments and structures. Increased temperatures in cities have resulted in substantial economic and health difficulties affecting more than half of the world's population. (J. S, , R. M, & C. A. G, 2018)

The main issue of research aimed targeting various aspects of the phenomenon, including awareness, experience, impacts, causes and potential mitigation strategies.

II. Problem statement

The urban heat island (UHI) effect is commonly acknowledged as a phenomenon where heat is accumulated, representing the most prominent feature of the urban climate arising from urban development and human activities.

This phenomenon results primarily from human activities known as Anthropogenic Heat Emissions (AHE) which are: road traffic, air conditioning systems and industrial activities generate heat, which is then trapped by greenhouse gases (such as carbon dioxide) that act as a barrier. Numerous scholars worldwide have conducted in-depth research on the characteristics of the Urban Heat Island (UHI) effect, establishing its close relationship with urban heat release, the properties and structure of the underlying surface, vegetation coverage, population density, and weather conditions. Additionally, the scale and intensity of the UHI effect will become progressively more serious with continued urbanization.

In this study, we targeted city of M’sila with less than 20% canopy cover (green spaces) and increased Temperature last years with more extremely hot days and prolonged heat, with daytime maximum temperatures of 47.7°C or warmer, with nighttime minimum temperatures of 44°C. This situation of warm is associated with many health, social and economic impacts and more serious effects, especially vulnerable person us outdoor workers, and people who are physically active outside. Overall, there is a pressing need for more extensive and in-depth research that systematically examines the economic, social, and environmental impacts of the issue which may pose threats to inclusive and sustainable development.

Research questions:

The following questions may therefore be asked are:

- What are the main causes of this phenomenon “UHI “?
- what are their effects and their mitigations?

III. Objectives and goals of the study:

The aim of the study is, therefore, to know what the concept of UHI means. Provide a comprehensive understanding of the main causes of this phenomenon and know many approaches, methods, models, and investigative tools have been implemented to study and analysis this phenomenon. Finally finding effective approach to mitigate urban heat island effects and bring comfort to residents.

We summarize all them through the following points:

- Comprehension the meaning of UHI
- Exploring the effects of urban heat island
- Understanding the main factors of this appearance
- Analyzing its effects on environment, human health and well-being.
- the perceptive of various approaches implemented to mitigate the UHI.

IV. Reasons for choosing this subject

although the impact of UHI in the form of heat waves are well-documented in developed countries, few studies cover cities in Algeria with in arid climate so I found myself

interested in this topic because I have seen and realized the impact of climatic factors in maintaining quality of life. I recognized that we have to take this case seriously and we must start looking for solutions to alleviate it before the matter escalates and becomes out of control.

V. Research Methodology

This master dissertation will use a mixed-methods approach and several interconnected processes, which are:

Literature review: A comprehensive review and relevant theoretical frameworks is conducted, examining previous research and published scientific articles on this topic.

Observations: Observations will be conducted in the selected urban area to gather data on the spatial and temporal patterns of temperature degree which make me obtain objective information that can be classified into defined categories and analyzed statistically in efficient ways.

Data Analysis: The data obtained through observational methods will be analyzed employing a mixed-methods approach. Quantitative data will be subjected to descriptive and inferential statistical analyses to discern patterns and explore relationships among variables. Qualitative data will be examined through thematic analysis to identify recurrent themes and meaningful patterns within the dataset.

Data Collection: To analyze the effects of heat island on the urban area, I collected data from different sources which was meteorological features, regional and urban structure characteristics.

VI. Tools and Criteria

Here I provide information about the tools and criteria used in this research to study the subject of causes and effects of urban heat island.

I highlight the role of Geographic Information Systems (GIS) which facilitated the mapping and spatial analysis processes by integrating geospatial data with diverse metadata, thereby enabling the identification of patterns and interrelationships within the urban environment. This integration provided a precise understanding of the interactions among various urban components.

This section focuses on the definition and justification of the selected criteria used to assess urban heat in the context of M’sila City.

Three primary criteria are explored: land cover and land use (vegetation and population density), construction materials, and land surface temperature. Each criterion is clearly defined, and corresponding indicators are identified to establish a comprehensive and structured framework for evaluation.

I use a typology and morphology method to analysis the UHI phenomenon in M’sila city.

The theoretical foundations and pertinent literature supporting each criterion are also discussed to ensure a solid conceptual basis for the research.

By translating these criteria into quantifiable indicators, the study seeks to provide an in-depth analysis of the contributing factors to urban heat in M'sila city.

The use of GIS data in this analysis facilitates the identification of both the city's strengths and the areas requiring targeted interventions.

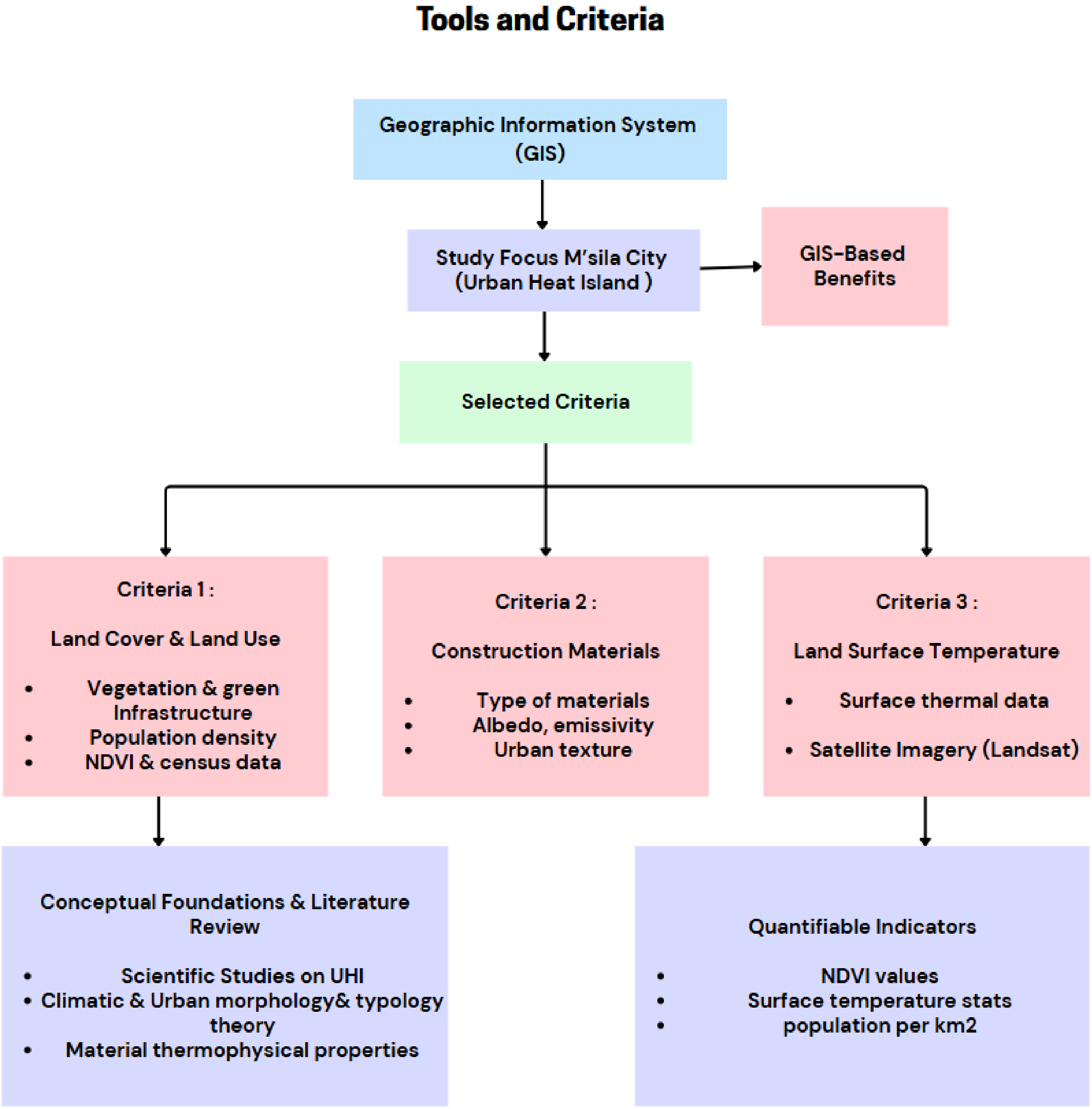


Figure I: Tools and Criteria organigramme **(By the Author)**

VII. Limitations of the study

Data Availability and Quality: Access to high-resolution temperature or land use data was limited, which may affect the accuracy of spatial analysis.

Spatial Limitations: The study area might be limited to certain neighborhoods or cities, which may not represent other urban or rural contexts or different climates.

Weather variability: unusual weather during the study period may have affected results.

Access limitations: Difficulty accessing certain urban areas or institutions for data or fieldwork.

Time Constraints: The research may be limited in scope and depth due to time restrictions, which can affect data collection, analysis, or inclusion of additional variables.

Despite these limitations, the findings provide valuable insights into the urban heat island effect and can inform future research and urban planning interventions

Comprehensive Literature Review

I. Introduction:

The Urban Heat Island (UHI) effect has emerged as a critical area of concern within urban environmental research, particularly in the context of rapid urbanization, climate change, and global sustainability agendas. Characterized by significantly higher temperatures in urban areas compared to their rural surroundings, the UHI phenomenon results from a complex interplay of anthropogenic modifications to land surfaces, alterations in energy balances, and the intensive use of materials with high thermal mass. These factors collectively lead to the absorption and retention of heat in urban fabrics, thereby exacerbating local temperatures and intensifying the challenges associated with urban living.

The significance of understanding UHI extends well beyond academic inquiry, the phenomenon has profound implications for public health, energy consumption, urban planning, and socio-environmental equity.

This literature review chapter aims to provide a comprehensive and critical synthesis of the theoretical and empirical research that has shaped current understandings of the Urban Heat Island effect. Drawing on a wide range of interdisciplinary sources.

This chapter explores the conceptual origins of UHI research, reviews its methodological evolution, and identifies key themes and debates within the field. Particular attention is paid to the mechanisms driving UHI formation, including land use patterns, vegetation cover, building materials, and anthropogenic heat emissions. In addition to examining the underlying causes of the UHI phenomenon, this review evaluates its observed and projected impacts at various spatial and temporal scales. It considers both the biophysical and socio-economic dimensions of UHI effects. The review also surveys current strategies for UHI mitigation and adaptation and interventions aimed at enhancing urban thermal comfort and resilience.

By clarifying essential terminologies, theoretical frameworks, and methodological approaches, this chapter aims to establish a strong foundation for the remainder of the dissertation. The goal is not only to contextualize the research within the broader academic discourse on UHI but also to identify existing gaps and emerging directions for future inquiry. In doing so, the chapter contributes to the advancement of knowledge in the field and provides a platform for a more focused examination of UHI impacts in the specific urban context under investigation.

II. Heat Island: Definitions and Causes

Many scholars around the world conducted deeply research on the characteristics of this phenomenon and tried to give various definitions about it and control it in certain terms like:

The UHI is an artifact of the complex built environment having a high density of human activities but lacks cooling vegetation, resulting thus in energy imbalances between urban and rural environments. Studies about the relationship between land use cover and the respective local climate (Kubota, et al., 2017) .In addition, UHIs have commonly been understood as a phenomenon in which the land surface temperature (LST) or near-surface air temperature over urban regions is higher than that in the surrounding rural areas. (Lili Tu, et al., 2016).

The scientists confirms that urbanization affects the microclimate and forms a unique urban climate environment such as the Urban Heat Island (UHI), referring to the phenomenon that urban areas are often several degrees warmer than the surrounding rural areas. (Kangning , Xia , Xiaoping, & Karen , 2019) and may contribute to the extra warming in addition to the warming already caused by climate change (Kangning , Xia , Xiaoping, & Karen , 2019).

Looking at this topic specifically, this fact situation was observed that today, it is the most studied climate effect of cities. (Chow, Brennan, & Brazel, 2012)

Based on the review of 75 studies (Deilami, Kamruzzaman, & Liu, 2018) determined the most common contributing factors of UHI such Urban geometry and density that influence urban microclimate due to the trapping of incoming solar and outgoing long-wave radiation, reducing turbulent transport due to wind shelter and releasing of anthropogenic heat. Further, increases in urban density are usually associated with changing surface properties due to decreasing green space and increasing build-up areas. (Oke, 1987).

The UHI is the one of the most obvious atmospheric modifications attributable to urbanization. It occurs in settlements of all sizes in all climatic regions. (Roth, Fernando, H.J.S, 2013) . The form and size of UHI vary in time and space and depends on meteorological features (e.g., cloud cover, wind speed, and humidity) and regional and urban structure characteristics (e.g., ventilation, surface waterproofing, thermal properties of the fabric, surface geometry). The development of UHI and the city’s thermal regime depends on solar radiation interaction with the urban atmosphere. Due to the complexity of the urban system, several levels of interaction may contribute to UHI formation. The first interaction occurs in the urban surface layer, where urban materials interact directly with the incoming radiation. At this level, the optical and thermal properties of the surface are dominant. The second level of interaction occurs in the complex airflow above the built environment. At this level, the physical processes are guided by surface properties and by local aerodynamics generated by canopy characteristics. The last is the interaction between the main physical flows and the whole city. (Georgiadis, 2017)

Urban construction materials have a higher heat capacity and can store more heat than natural materials, such as trees, dry soil, and sand. Urban pavements with low thermal conductivity can heat up at the surface but will not transfer heat into the other pavement layers as fast as the pavement with higher conductivity. The thermal conductivity of pavement depends on the type of mixture, aggregates used, percentage of each component in the mixture, and its compaction level. Regarding aggregate base materials or subgrade materials, the thermal conductivity depends on factors such as type of material, mineral content, moisture content, particle size, and overall density. Besides, the thermal behavior of pervious material depends on its porosity which influences surface energy fluxes. (Stempihar, Pourshams-Manzouri, Kaloush, & Rodezno, 2012)

Big part of the urban land occupation is composed of high density of buildings and large paved and impermeable areas, which supports the high increase of the air temperature in the urban centers, which creates microclimates in different zones of the city, causing the heat islands. (Bruna , Júlia Calvaitis , Paula, Fabiane , & Natalia) .scientists has shown that in most cases, UHIs tend to form over built-up areas such as industrial or commercial areas; on the contrary, 'cool islands' have been observed in vegetated areas such as parks and forests. (Ongsomwang, Dasananda, & Prasomsup, 2018) . The ability of materials to capture heat depends on thermal inertia in addition to other thermal properties. Thermal inertia is related to the ability or material to resist a variation in heat flow or temperature and is defined as the speed at which a material cools or heats up. Thus, inert material is a material that takes a long time to reach a new equilibrium temperature when subjected to a thermal perturbation |. (Sidler, 2003) . The absorption of day-time incoming solar energy is the primary source of UHI phenomena during summer seasons. In generally, pavements and roofs comprise over 60% of urban surfaces. (Akbari, Bretz, Kurn , & Hanford, 1997) .The absorption capacity of dark materials, dark pavements and roofs are 80–90% and light materials, white roofs and light-colored pavements are 30–65% of the incoming solar energy. Hence, the use of reflective building surface materials is a critical solution for UHI mitigation. (Ansar, et al.) .

The differences in temperatures across the urban areas depend on the land cover types. (Grimmond, 2007)Temperatures of dark, dry impervious surfaces in direct sunlight can reach up to 88 °C during the day, while vegetated surfaces with moist soil under the same conditions might reach only 18 °C . (Gartland, 2008) Unlike smooth rural areas, in urban areas, the airflow is reduced due to the rough surfaces. Paved surfaces cover a significant percentage of urban areas and play an important role in UHI formation. (Taha, 1997)

UHI intensity is often measured by the difference in a weather station of urban area and one in a less urbanized outskirt, which is generally named as surface air UHI phenomena. (Arnfield , 2003) (Stone, 2007) (F, 2009) .Since the spatial density of in situ weather stations is sparse and usually influenced by local environment. So, it is very difficult to rely on these data alone for obtaining information about UHI at city-scale. (Walter Leal Filho, Gustavo J. Nagy · Marco Borga ·, Pastor David Chávez Muñoz ·, & Artur Magnuszewski Editors, 2010)

In neighborhood scale, the UHI effects are closed to the urban surface; surface temperature has an indirect effect, but significant influence on air temperature and thermal comfort of urban environment. (Bretz SE & Akbari , 1997) . City-scale modeling of UHI is a challenging task to urban climatologists and geographers using satellite remote sensing (SRS) data. The SRS data are important devices to spatial correlate surface air temperatures and land use-land cover (LULC) of a city area. For this, SRS is now offering the opportunity to characterize spatio-temporal structures of land surface temperature (LST) with available resolution to discriminate between urban and rural thermal anomalies. (Voogt & Oke, 2003) (Wan, 2008)

The contributing factors to UHI formation can be summarized as follows: the increase in impervious surfaces, modification of urban geometry, low albedo of urban materials, the increase of population and release of anthropogenic heat and the absence of vegetation. (Wijeyesekera, et al., 2012)

The thermal behavior of urban materials depends on the thermal physical properties related to energy transport through a system (e.g., radiation, conduction, convection) and properties related to the thermodynamic or equilibrium state of a system (e.g., density, specific heat capacity). (Georgakis & Santamouris, 2017)

It is important to better understand what climate change hazards are, how the different components of climate change including frequency, intensity, variability and uncertainty play together and relate to ecosystems, and how a better understanding of vulnerability of people to climate change in terms of sensitivity can be achieved. Also, it is equally important to identify adaptation options based on the adaptive capacity—which does vary—between sectors, populations and ecosystems. (Walter Leal Filho, Gustavo J. Nagy · Marco Borga ·, Pastor David Chávez Muñoz ·, & Artur Magnuszewski Editors, 2010).

III. Results of this phenomenon

Previous studies have demonstrated the effect of urban sprawl on public health, air quality and urban water use. The surface urban heat island (SUHI) effect is an important indicator of the environmental consequences of urbanization and has rapidly changed the dynamic (Lili Tu, et al., 2016)s. One of the most important factors influencing the quality of life in urban areas is the urban microclimate. (Rehan, 2016) . The elevated temperatures in urban areas impact urban environmental quality and human well-being. (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017) . The consequences of the UHI are various such as degradation of the living environment, increased cooling energy usage and associated costs, intensification of air quality problems (e.g., the formation of large amounts of smog and air pollutants), impact on human health, comfort, and increased thermal stress and water quality deterioration. (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017) it also amplifies the summer heat wave and pollution related human mortality, decreasing the human physiological comfort and promoting the average and peak energy demand of buildings. (Mirzaei, 2015)

Accurate measurements of the effects and changes resulting from the SUHI effect may provide useful information for urban planning. Index, centroid transfer, and correlation.

The increases in global surface temperature have been paralleled with the frequency and intensity of temperature extremes. (Ansar, et al.) . Due to the increased temperature, and as a result of the release of heat from buildings, vehicles and due to human activities, people in urban areas in India and elsewhere have been experiencing very hot weather in the summer months. Low wind speeds in urban areas also hinders the entry of fresh air. (Ansar, et al.)

Globally, heat extremes have adverse effects on human health and well-being, cause human discomfort and heat stress (Abdel-Ghany, Al-Helal, & Shady, 2013)

When body temperature exceeds over 41 °C, heat stroke and even death can occur. This disturbs the thermo-regulation process of the body causing fever, increased pulse, and hot and dry skin. Heat-related illnesses occur as a result of exposure to high temperature over a period of time which includes heat syncope, heat cramps, heat exhaustion, heat stroke and eventually death.) George و Michael (2008 ،

IV. The impacts of Urban Heat Island, signs & symptoms and its effect

Impacts of UHI	Signs and symptoms	Effect
Heat stroke	• Body temperature suddenly rises to more than 40 °C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. • Hot, dry skin, hypotension, nausea, tachycardia and tachypnoea are frequently present	Cardiovascular system, central nervous system abnormality, decreased kidney's function, and muscle cramps.
Heat cramps	•Painful muscular spasms occur, in the legs, arms or abdomen, usually at the end of continuous exercise • This can lead to dehydration, loss of electrolytes through heavy sweating and muscle fatigue	Muscle spasms, cardiovascular system, metabolic system
Heat oedema	Oedema of the lower limbs, typically ankles • This is attributed to heat induced peripheral vasodilatation and retention of water and salt	Kidney damage
Heat exhaustion	•Severe thirst, weakness, discomfort, anxiety, dizziness, fainting and headache • Pulse is rapid, with postural hypotension and rapid shallow breathing • Core body temperature less than 40 °C	Cardiovascular system, kidney damage, muscle cramps, CNS abnormality
Depression, aggressive behavior, anxiety, mental stress	•Reduced emotional well-bring, irritable, feeling agitated, restlessness, fatigue, increased emergency room visits	Psychological illness
Heat rash	•Small, red, itchy papules on the face, neck, upper chest, under breast, groin and scrotum areas • More prevalent in young children	Affects skin

Table 01: WHO-Heatwave and Health: Guidance on warning system development (2015).

V. Challenges:

The increasing summer temperatures not only undoubtedly increase the cooling power consumption but also might increase the risk of summer heat wave over the study area; this makes the worse climate in city in terms of local and regional circulations of winds. Now, a big challenge is faced by urban climatologist and geographers to establish a protocol between process of urbanization and city climate by means of different climate forcing extreme events. It would be understood how to adapt and mitigate summer heat wave induced by climate variability and UHI phenomena. Therefore, a better understanding is needed to know the nature of UHI pattern, which is a critical important for the study of urban climate and subsequent sustainable urban planning. (Ansar, et al.)

To countermeasures this super-fluous phenomenon, a string of approaches and policies were recommended and accustomed to the cities Also to assess the impact of light-colored surfaces (roofs and pavements) and urban green coverage (trees, grasses and shrubs) on meteorology and air quality of the city, it is indispensable to accurately characterize the various unreceptive urban surfaces. (Akbari, Rose, & Taha, Analyzing the land cover of an urban environment using high-resolution orthophotos., 2003)

VI. Example:

The Kolkata metropolitan area (KMA) is one of the sub-tropical urban environments experiencing swift and incessant urbanization process that has resulted in significant energetic differentiation in rural-urban domain as advection of heat wave and urban heat island (UHI) effect, it has to persuade on urban climate, biological environment and socio-economic atmosphere of urban society.

The preparation of UHI susceptibility zonation is the preliminary measure for UHI risk assessment and hazard mitigation. The present study has been adopted the city-scale modeling of UHI by means of geographic information system (GIS) based statistical models for building the UHI susceptibility zonation using remote sensing (RS) data and other ancillary data.

The present study of city-scale UHI modeling was conducted on Kolkata metropolitan area (KMA), delimited by the latitudes of 22.01°N and 23.08°N, and the longitudes of 88.03°E and 88.45°E, developed mainly along the banks of the river Hugli about 150 km to the north of the Bay of Bengal (BoB), right over the Gangetic delta plains. Figure 1 depicts the study region, which are urban and suburban Kolkata. The KMA is one of the leading metropolises in the urban world and third largest urban agglomeration in India. It provides major financial hub of east and northeast India and also supports crucial industrial and transportation facilities to hinterland regions. The population of Kolkata is increasing trend as 1.5 million in 1901, 11 million in 1991 and a phenomenal 14.2 million in 2011. The concentration of population is univocal, in a few parts of city comprises population density >100,000 persons/km2.

The UHI of KMA are affected by a series of conditioning factors such as socioeconomic, structural and radiative drivers due to it emblematic urban attributes.

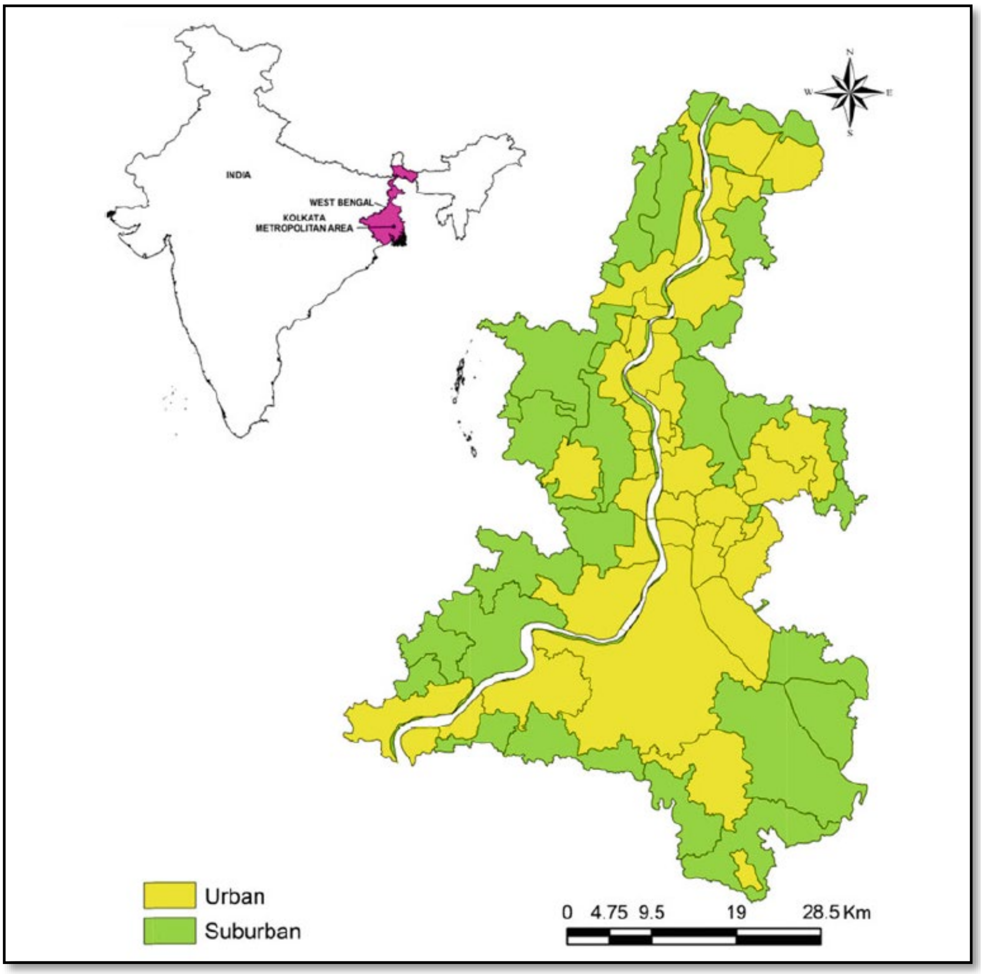


Figure 02: Location map of Kolkata metropolitan area (KMA) and suburban-urban structure

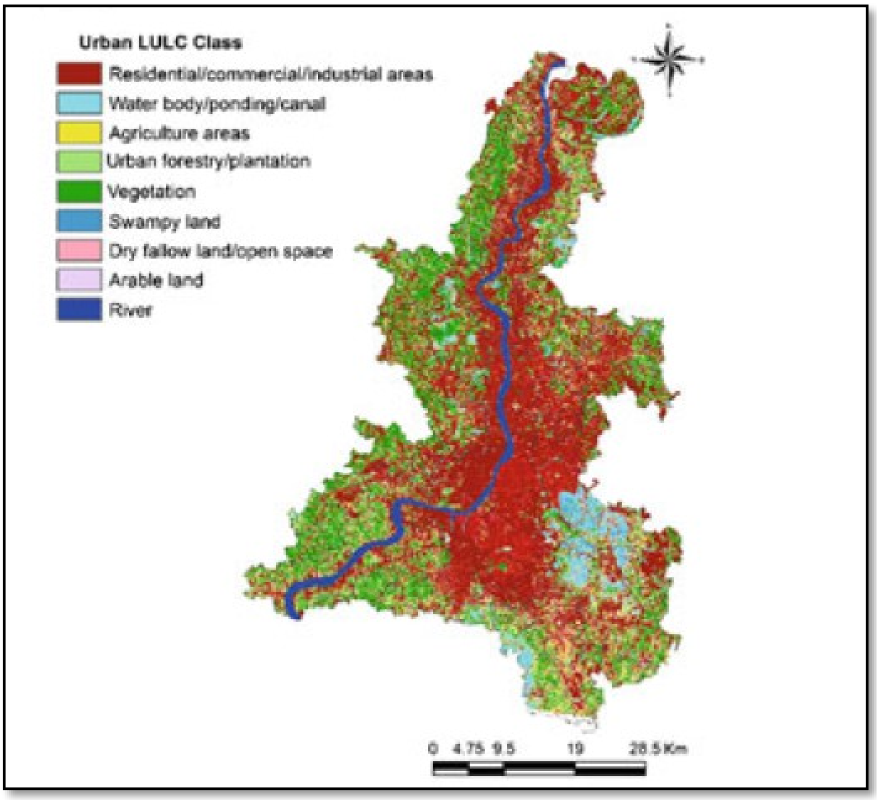


Figure 03: land use/land cover of Kolkata

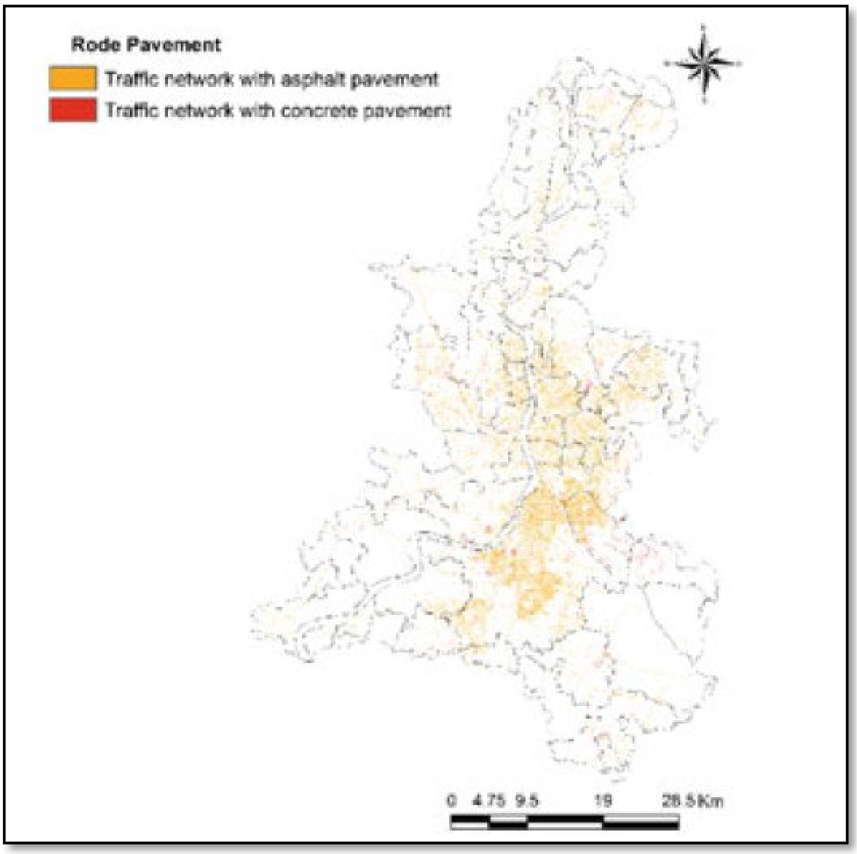


Figure 04: road pavement in Kolkata

The spatial distribution of UHI pattern has been changed as of a mixed pattern, where open bare land, semi-bare land and other land going to be developed were warmer than other unreceptive urban surface to all-embracing UHI centers (The LULC of urban centers provides the information concerning predominant urban surface types and other socio-economic attributes. The present LULC classification of KMA has been extracted by carrying out an object-based approach on national atlas and thematic mapping organization (NATMO) scheme of nomenclature The regional scale LULC classes were designated by the association of building blocks, water bodies, agricultural fields, vegetation coverage, plantation areas, wet lands and open bare lands etc.

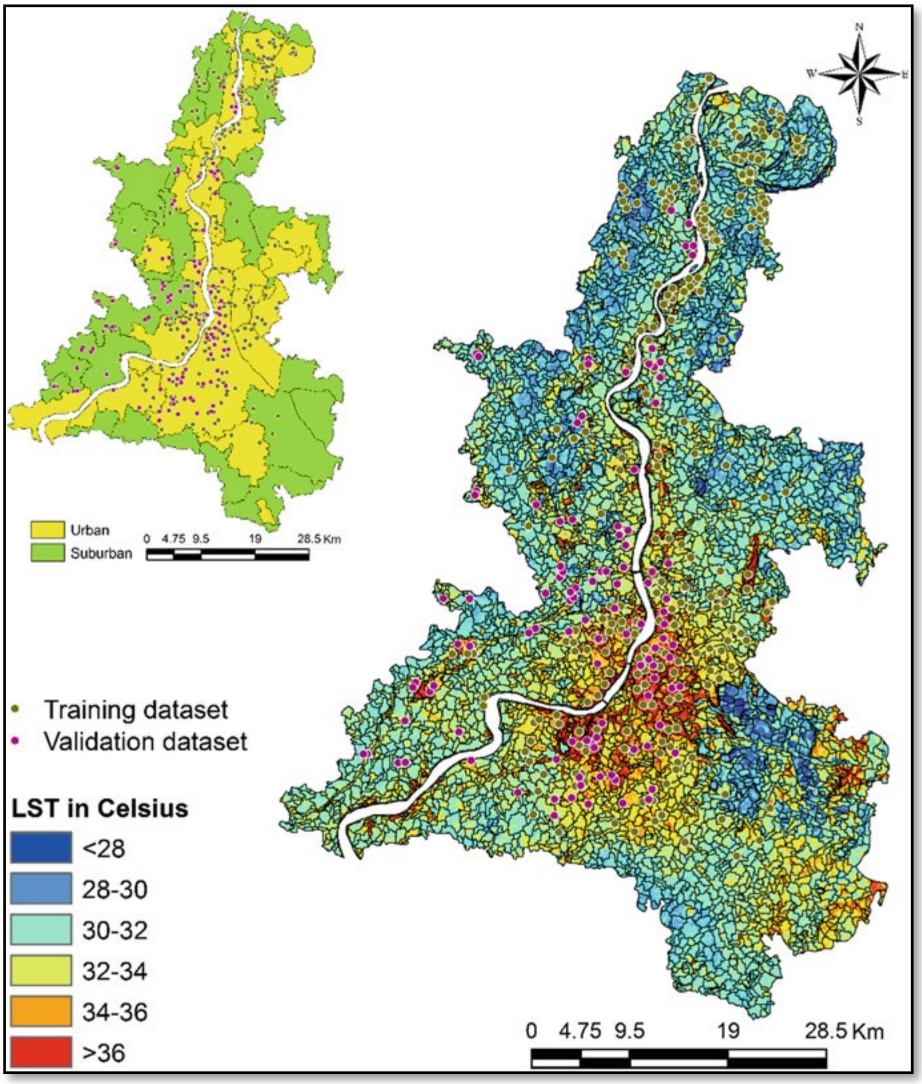


Figure 05: Final urban heat island inventory map extracted from Landsat TM satellite images

Conclusion*:*

In summation, the foregoing analysis underscores the extent to which the Urban Heat Island (UHI) phenomenon remains insufficiently explored and inadequately governed within both academic and policy spheres.

The evident scarcity of comprehensive, interdisciplinary research on UHIs signals a pressing imperative for expanded scholarly inquiry and the formulation of targeted regulatory frameworks.

A nuanced understanding of the multifaceted impacts of UHIs is essential to inform strategic urban planning, foster inclusive socio-economic development, and enhance climate resilience.

Consequently, future academic and legislative initiatives should prioritize bridging this critical knowledge gap by constructing an integrative approach that captures the complexity of the UHI phenomenon and supports the development of sustainable, evidence-based urban policy responses.

PRESENTATION OF M'SILA CITY

Introduction:

This chapter offers a comprehensive and multidimensional analysis of the city of M'sila, with a particular focus on the growing environmental challenge of the Urban Heat Island (UHI) effect.
As urbanization continues to reshape cities across the globe, understanding the causes and impacts of UHI has become critical especially in regions like M'sila, which are characterized by rapid urban growth and a semi-arid climate.

M'sila, located in the heart of Algeria, serves as a significant case study due to its distinct climatic conditions, evolving urban structure, and increasing population density.
Over the years, the city has undergone substantial transformation in terms of land use, infrastructure development, and demographic expansion factors that collectively contribute to noticeable temperature differences between urban and surrounding rural areas.

By synthesizing data and insights from multiple dimensions (climatology, urban planning, demography, and environmental science) ,
This research aims to clarify the interplay of these factors in producing the urban heat island effect in M'sila.

By examining these interconnected dimensions This chapter provides valuable insights into both the challenges and opportunities that lie ahead for M'sila in addressing urban heat and enhancing environmental sustainability.

I. M’sila City Location:

The city of M’sila is centrally located within the national territory, situated in the Al-Hodna basin, approximately 100 km from Bejaia. It lies at an elevation of 470 meters above sea level and is traversed longitudinally by the Cane Valley from north to south. Additionally, M’sila serves as a key intersection for three major transportation routes: National Roads 40, 45, and 60.
As the administrative center of both the province and municipality, M’sila spans an area of approximately 232 km². According to 2014 municipal statistics, the city's urban center covers about 50.01 km². The total population is estimated at 214,661 inhabitants, with a population density of 925 people per km².

I.1 Geographical Coordinates

The city of M’sila is situated between the equator (35.48°) and (35.67°) north latitude and (4.48°) and (4.57°) east longitude from the Greenwich meridian.

I.2 Administrative Location

The Municipality of M’sila is situated at the northern boundaries of the M’sila province and is defined by these limits:

- **To the north:** Bordered by the Municipality of Al-Eush, within the province of Bordj Bou Arreridj.
- **To the east:** Adjacent to the Municipality of Matrafa.
- **To the south:** Borders the Municipality of Suma.
- **To the west:** Neighboring the Municipality of Ouled Mansour.
- **To the southwest**: Shares a boundary with the Municipality of Ouled Madhi.

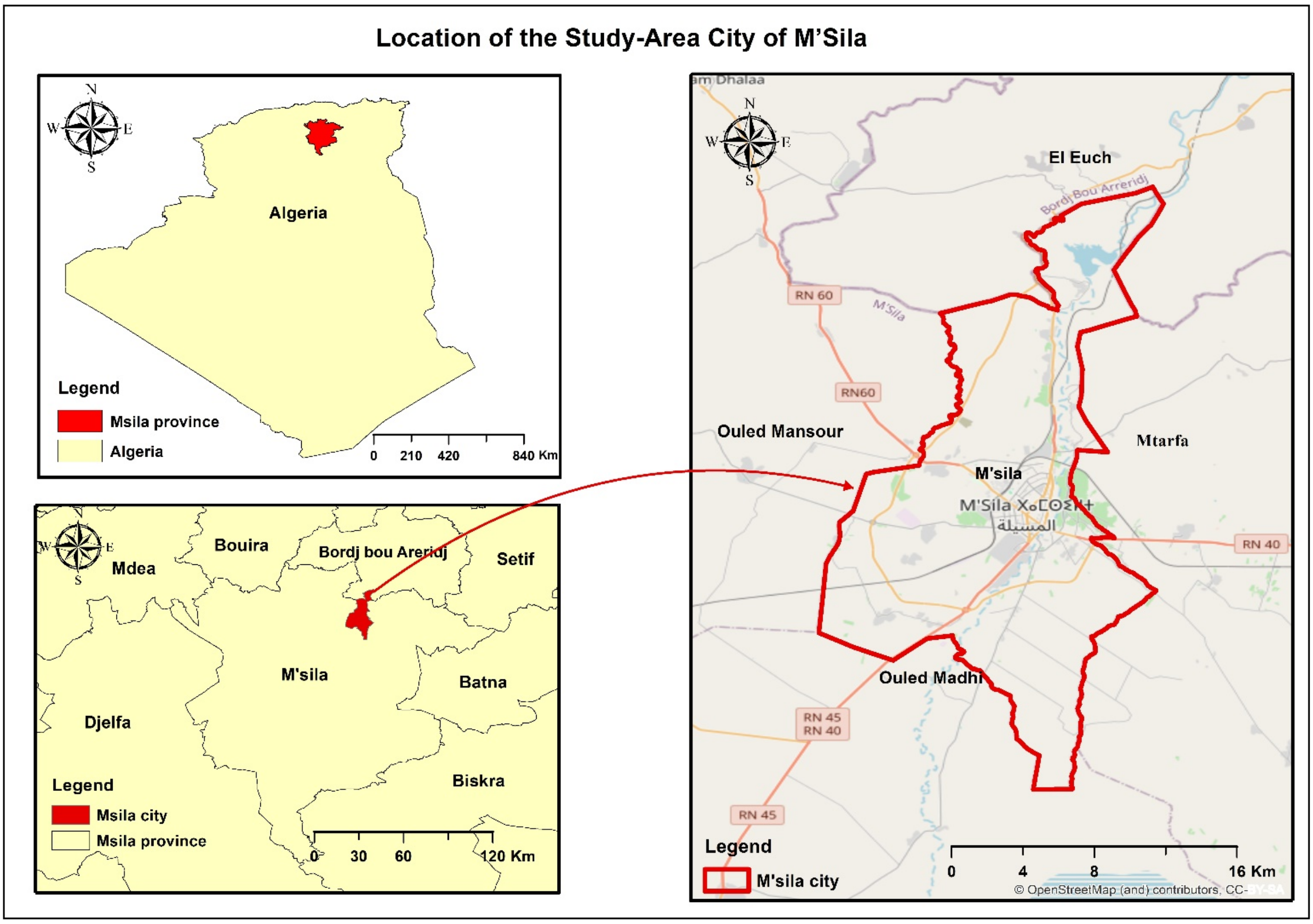


Figure 06: Location of the Study-Area City of M'Sila **(By the Author)**

II. A Historical Overview of the City's Growth and Evolution:

The city of M'sila, like any other ancient city, went through several stages, with different features Each stage has established the first nucleus near the area of (Beshilga), which is currently about 30 km away.

The initial stage (pre-1830) is categorized into two distinct periods: the Roman period and the Arab-Islamic period. The second stage encompasses the period of French colonization, which lasted from 1830 to 1962. The third stage extends from 1962 to 1986, while the fourth stage begins in 1986 and continues to the present day.

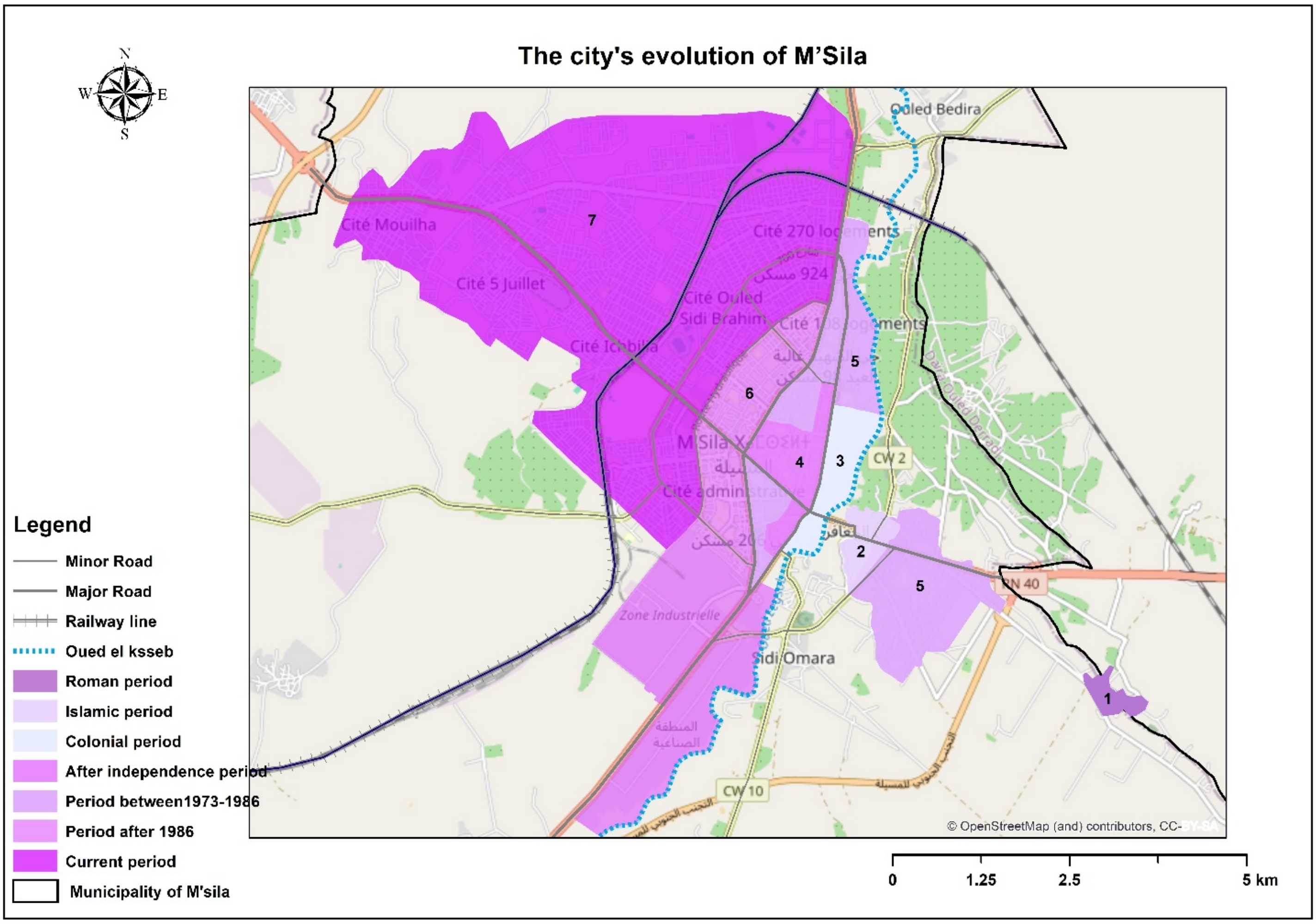


Figure 07: The city's evolution of M'sila **(By the Author)**

III. The Urban Analysis:

a. Urban Sectors:

For a comprehensive and objective analysis, the city has been systematically divided into distinct urban sectors. This segmentation enables effective comparison, interpretation, and assessment of various urban dynamics. By examining these sectors, it becomes possible to identify future demands and ensure the equitable distribution of essential services, including healthcare, education, transportation, and recreational facilities. Additionally, such studies play a crucial role in enhancing urban infrastructure by evaluating its current state and prioritizing necessary improvements.

Sector number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Area (ha)	**1241.23**	**425.47**	**268.42**	**257.59**	**611.67**	**437.81**	**570.84**	**854.88**	**503.29**	**5171.20**
Percentage (%)	**24.00**	**8.23**	**5.19**	**4.98**	**11.83**	**8.47**	**11.04**	**16.53**	**9.73**	**100 %**

Table 02: compiled by student utilizing data provided by the Statistical Office of the Municipality of M'sila.

The table presents the spatial distribution of urban areas across different sectors of the city, highlighting the varying land areas and their respective proportions. This classification provides valuable insights into the city's structural organization and land use patterns, offering essential implications for urban planning and the equitable allocation of services.

Sector 1:

Sector 1 encompasses the largest urban area, covering 1,241.23 hectares, which accounts for 24% of the city's total area. As the oldest part of the city, it represents the historical civic center and serves as the foundation of the city's urban development

Sectors 2, 3, and 4:

These sectors have comparatively smaller areas, ranging between 257.59 and 425.47 hectares, collectively comprising 18.4% of the total urban space. They form the city center, characterized by high commercial activity and a concentration of essential services, making them key hubs of economic and social interaction.

Sector 5:

This sector covers 611.67 hectares, representing 11.83% of the total urban area. It is medium-sized and houses higher education facilities, including Mohamed Boudiaf University. Additionally, it is the last sector that forms part of the central urban zone.

Sectors 6, 7, and 8:

These sectors range in size from 437.81 to 854.88 hectares, together constituting approximately 36% of the city's total area. They are divided by National Road No. 60, which connects to Algiers. Sectors 6 and 7 are predominantly residential-commercial zones, while Sector 8 is a newly developed area established after the early 2000s to address housing shortages. Located in the northern part of the city, Sector 8 is characterized by community housing developments.

Sector 9:

Covering an area of 503.29 hectares and comprising 9.73% of the total city area, Sector 9 represents the latest expansion zone. Located in the northwestern part of the city, it includes AADL collective rental-sale housing, reflecting the city's urban expansion trends.

Sector 1	**Larocade**
	El-Djaafra
	El-Koushe
	El-Argoub
Sector 2	**Waewae el-madani**
	El-Zahir
	El-Noubala
Sector 3	**El-Nasser 1000 residence**
	322 residence
	Hay el-idari
	villa rose
	El-Nahdha
	206 residence
Sector 4	**500 residence**
	Ibn rouchaik police school
	924 residence
Sector 5	**Ewlad Sidi Ibrahim**
	700 residence
	270 residence
Sector 6	**Echbilia**
	504 residence
	608 residence
Sector 7	**05 July**
	Mouilha
Sector 8	**3000 and 560 residence**
	El-Kia
	New urban pole
Sector 9	**1600 residence AADL**
	600 residence AADL

Table 03: Distribution of neighborhoods to sectors **(By the Author)**

The table illustrates the distribution of neighborhoods across the nine sectors of the city of M'sila, highlighting variations in the number of neighborhoods within each sector. This distribution reflects the diversity of housing patterns across different areas, offering a comprehensive perspective on the urban and social landscape of the city.

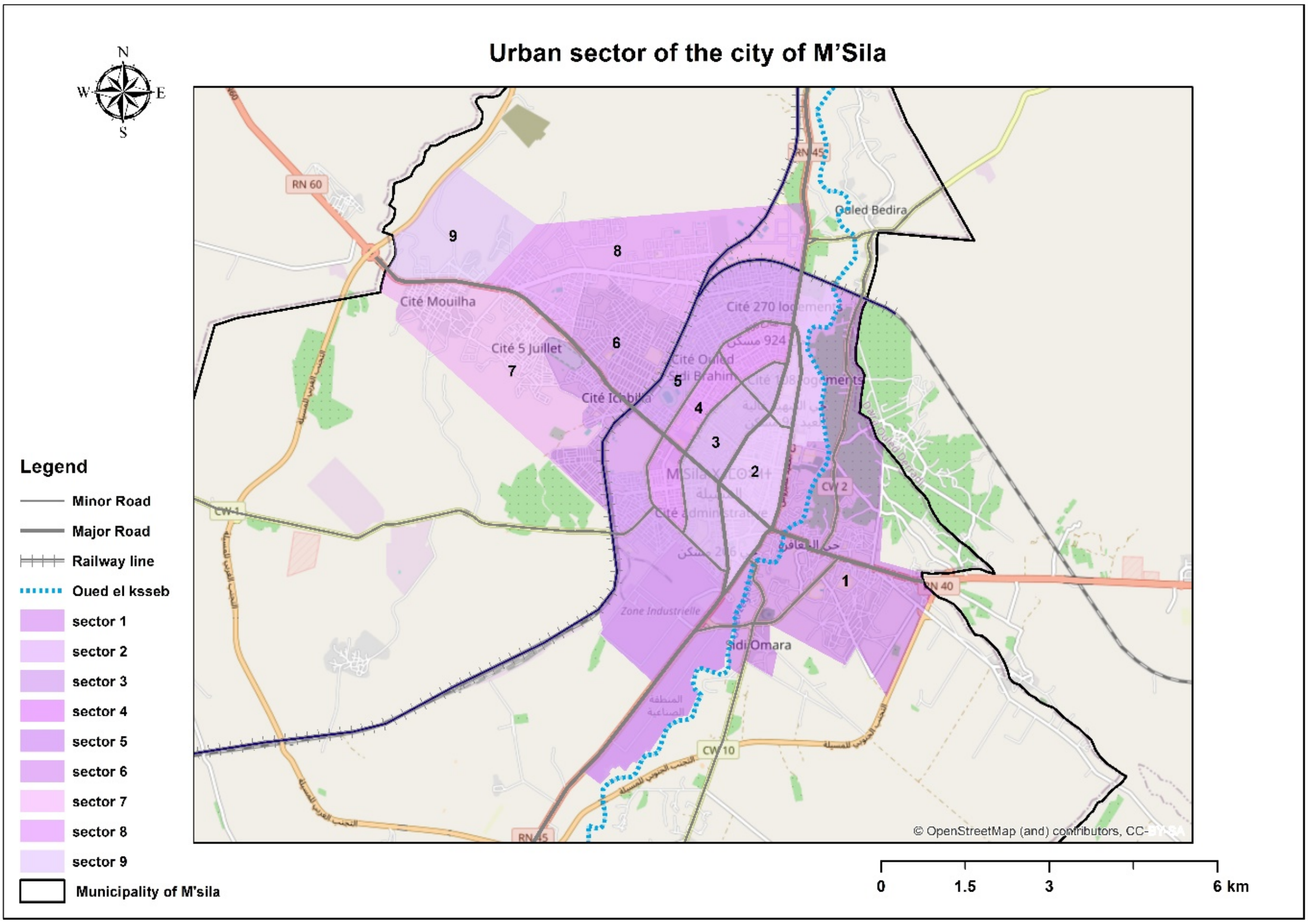


Figure 08: Urban sector of city of M'sila **(By the Author)**

b. Structured roads of the city:

The structured road system of M'sila city is a key element of its urban development, reflecting both its historical influences and modern planning. Over the years, the city's road network has been shaped by various phases, from ancient Roman routes to the strategic layout during the Arab-Islamic period, and later, developments under French colonization. Today, the city boasts a well-organized road system designed to accommodate its growing population and improve connectivity within the region. This system plays a significant role in facilitating transportation, trade, and urban mobility

b.1 rail line:

The city of M'Sila is strategically connected to the town of Barika in Batna Province to the east and to the city of Bordj Bou Arreridj (B.B.A) to the north, while also being linked to the national railway network.

b.2 National Roads:

National Road N45: crossing from the north of the state the borders of the Bordj
Bou Arreridj to the south of it through the center of the city.

National Road N40: which extends to the eastern side of M'Sila City and connects it to each of the opposing countries, and is the eastern entrance to the city.

National Road N60: extends northwards to M'Sila City and connects it to Algiers
through the Hammam El Dalaa.

b.3 Provincial Roads:

State Road N01: which runs from Beshilga East to the border with the town of Ouled Mansour West through the city center.

State Road N02: which blazes the city from the north of the village of Ouled Bdairah
through the DJaafarah neighborhood in the center of the city to the south of
the city link with the town of Ouled Madi.

There are several municipal roads that connect villages and small settlements, which are suffering from significant deterioration due to a lack of maintenance over a long period of time. Some of the Most important of these roads include:

- The municipal road connecting the provincial road of Ouled Mansour in the village of Ghazal, and then the National Road 45.
- The municipal road connecting Hjajiya and the provincial road N01 Ouled Madi, M'sila.
- The municipal road linking Mazrir, Ouled Ali Ben Zaid.
- The municipal road linking the El Kasab (Al-Baraj) with National Road N 45.
- The municipal road connecting Nuwara with the Larokad neighborhood.
- The municipal road linking Provincial Road N01, M'sila, Ouled Mansour, and then the village of El Lehasn.
- The municipal road connecting Ouled Bdaira and Ouled Salama.

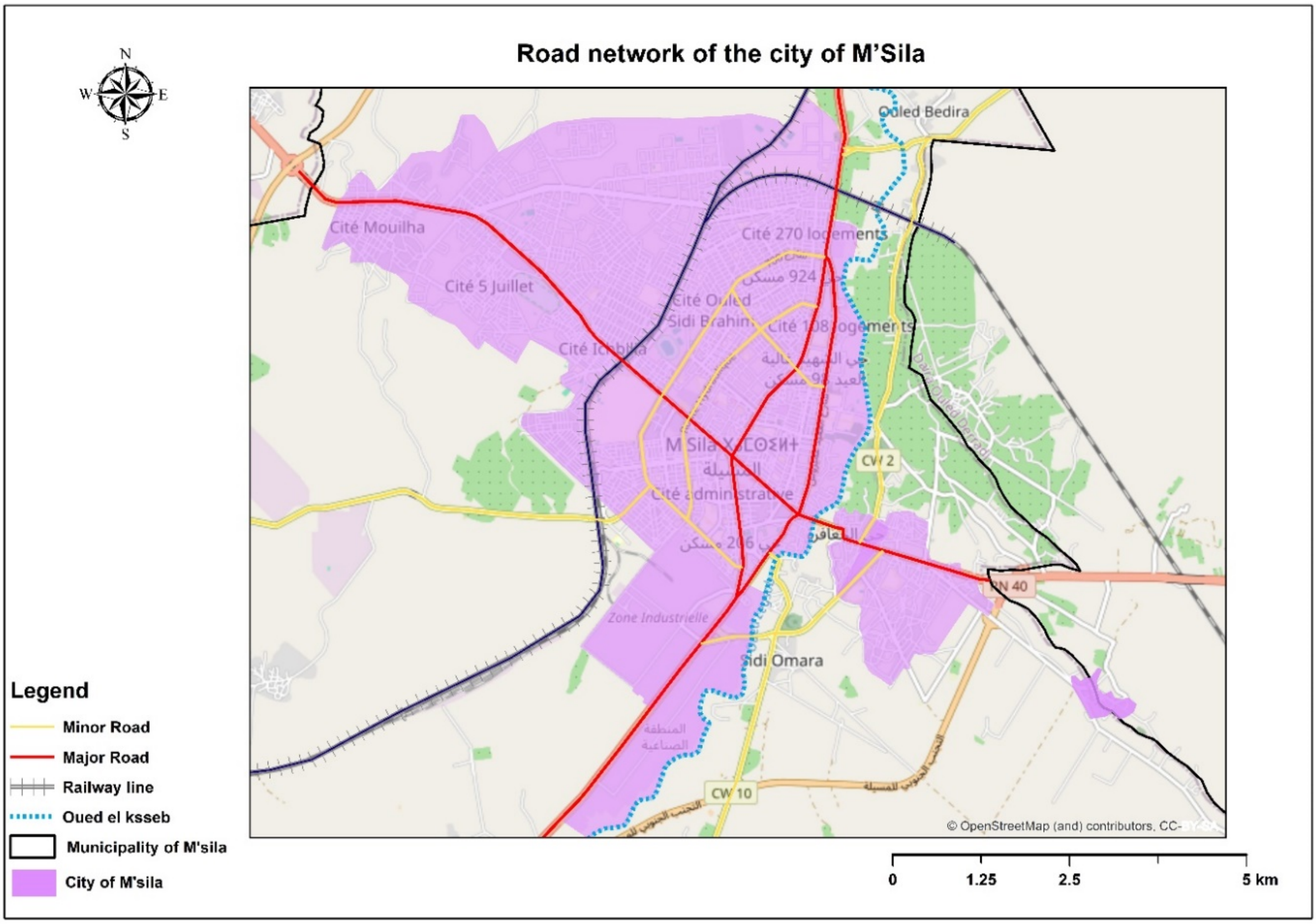


Figure 09: Road network map of the city of M'Sila **(By the Author)**

c. City’s Facilities:

The facilities in the city of M'sila include various structures and institutions that support community and urban functions, such as health, educative, administrative facilities and commercial services. These essential facilities contribute to the city's urban identity, while also offering services that cater to the daily needs of its population.

Here it is the table which summarizing the number of facilities in the city.

Table 04: Equipment in the city of M'sila

Category of facilities	Numbers	Percentage (%)
Health facilities	12	3.61
Education facilities	96	28.91
Administrative facilities	86	25.9
Religious facilities	71	21.38
Sports facilities	9	2.71
Security facilities	14	4.21
Tourist facilities	6	1.8
Financial and insurance facilities	23	6.92
Cultural facilities	13	3.91
Transport stations	2	0.6
Total	332	100

Source: compiled by student utilizing data provided by the Statistical Office of the Municipality of M'sila.

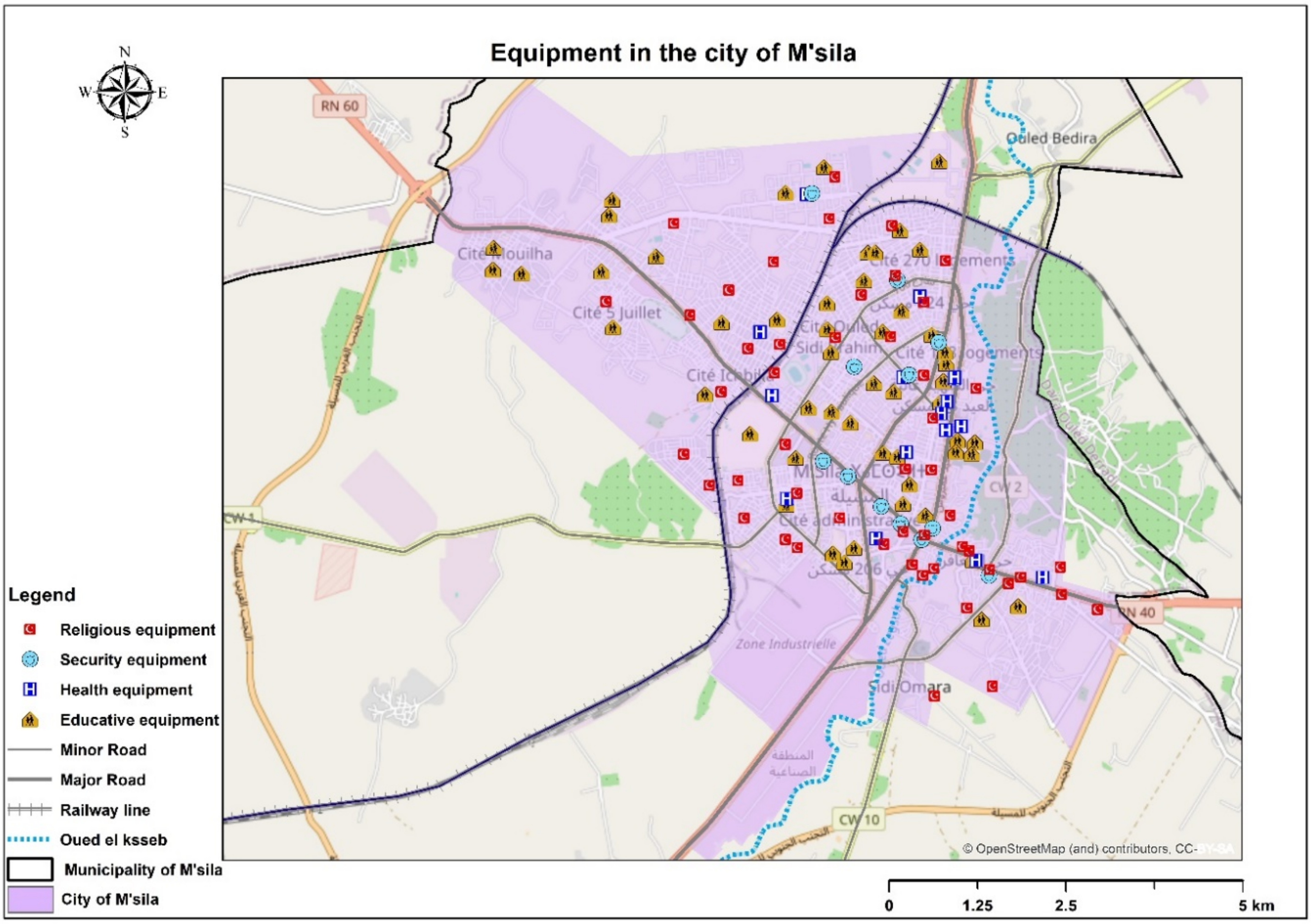


Figure 10: Equipment in the city of M'sila **(By the Author)**

d. Housing:

Housing is a crucial aspect of the city, and understanding its role within the urban environment requires a thorough analysis. Urban and demographic changes influence housing, which in turn directly impacts the quality of life and well-being of the city's residents. According to the data from (Table No 08), significant growth in housing has occurred over the past few decades. The population increased from 6,281 in 1977 to 13,735 in 1987, marking a 54% rise. The number further grew to 20,119 in 1998, reflecting a 30% increase. This growth continued, reaching 23,420 in 2008, a rise of 18%. Between 2008 and

2019, the most substantial increase occurred, with the population surging to 45,394, nearly a 94% growth. This increase is also attributed to government policies and ongoing housing development efforts.

Table 05: The development of housing

years	1977	1987	1998	2008	2019
Number of houses	6281	13735	20119	23420	45394

Source: compiled by student utilizing data provided by the Statistical Office of the Municipality of M'sila

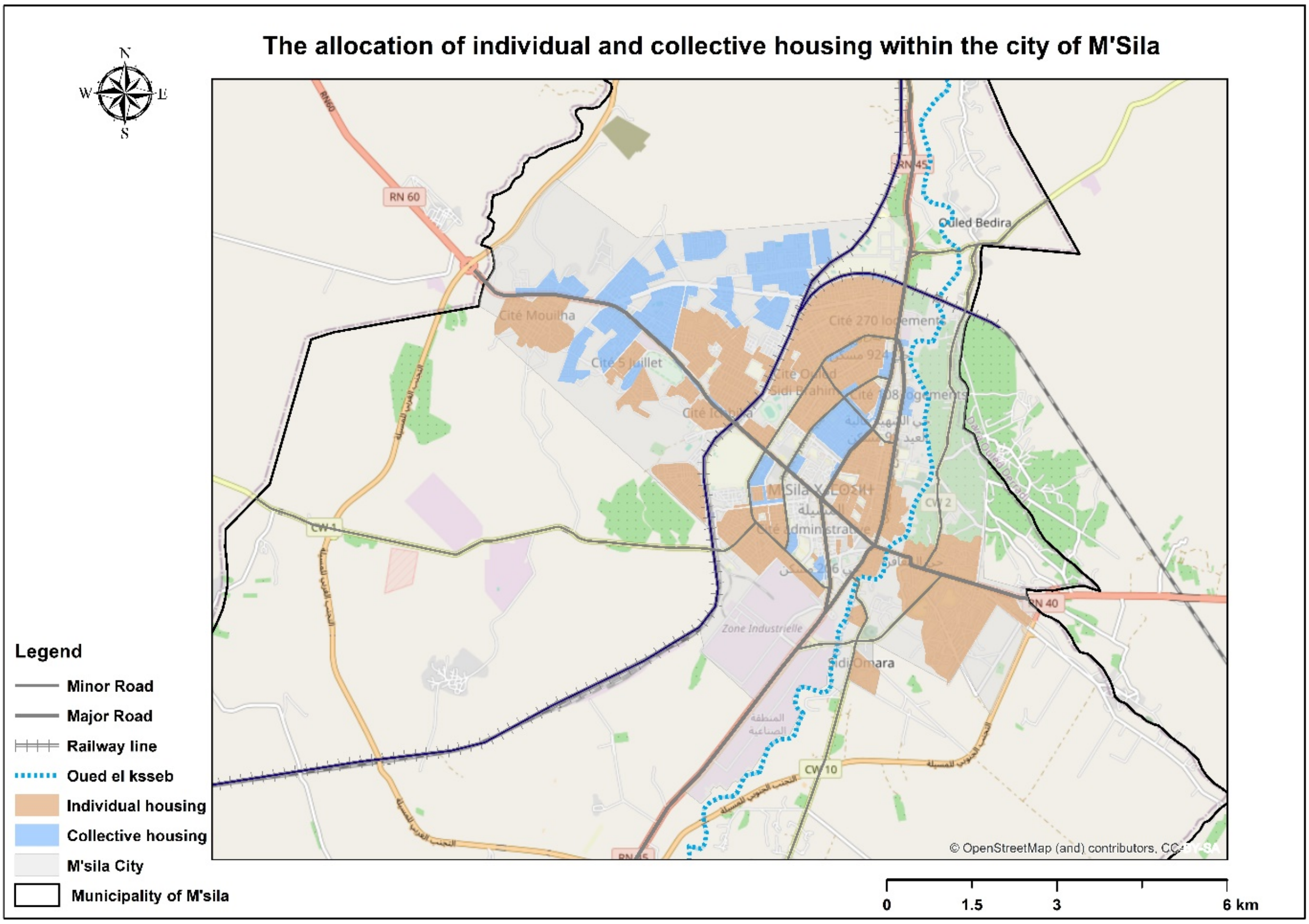


Figure 11: The allocation of individual and collective housing within the city of M’sila **(By the Author)**

e. Population Density

Higher population density in urban areas leads to more human activities, such as transportation, construction, and energy consumption. This increases the amount of heat released into the environment, contributing to the urban heat island effect. The larger the population, the more intense the heat retention, especially in areas with poor ventilation and limited green spaces.

Table 06: Population density

	population					
years	**1966**	**1977**	**1987**	**1998**	**2008**	**2019**
City of M'sila	19657	29512	65805	102151	123975	203029

Table 07: Annual Percentage of City Development

	Annual Percentage				
years	**1966/1977**	**1977/1987**	**19871998**	**1998/2008**	**2008/2019**
City of M'sila	4.06	8.02	4.4	2.64	3.06

Source: compiled by student utilizing data provided by the Statistical Office of the Municipality of M'sila.

According to the tables It turns out that the growth rate there has been an increase in recent years and This shows the improvement that's happened.

f. socio-economic study:

A socio-economic study is crucial as it forms the foundation for future planning processes. It aids in understanding and clarifying spatial relationships, as well as various population, historical, and functional dynamics in human life. Furthermore, it plays an essential role in paving the way for effective planning and preparation.

f.1 The economic makeup of the city's population:

examining the economic composition of the city's population is crucial as it offers a thorough understanding of the community's economic structure. By analyzing various population groups, such as employed individuals, the unemployed, those who are able but unwilling to work, and those outside the working age, it highlights the strengths and weaknesses of the local economy. This analysis is valuable in enhancing job opportunities and delivering essential support to the most vulnerable groups.

Table 08: Economic composition of the city's population

Category	Number	Percentage (%)
In working Age	109311	53.84
Manpower	68116	33.55
Non-working population	41195	20.29
Unemployed	18232	8.98
Young people	85597	42.16
Actually working	49823	24.54
Out of working Age	93718	46.16
Old people	7309	3.6
Total population	**203029**	**100**

Source: compiled by student utilizing data provided by the Statistical Office of the Municipality of M'sila.

Employed Population: This category comprises individuals who were actively engaged in employment during the year 2019. The employed population was estimated at approximately 2,019 individuals, accounting for 33.55% of the total economically active population.

Unemployed Population: This group includes individuals within the 15–65 age bracket who were not employed in 2019 but were actively seeking work. The number of unemployed persons was approximately 18,232, representing about 8.98% of the city's total population.

Non-participating Working-age Population: This segment includes individuals aged 15 to 65 who, despite being within the legal working age, were not engaged in the labor force due to personal or social reasons. This includes homemakers, students, and persons with disabilities. In 2019, this group comprised approximately 41,195 individuals, representing 20.29% of the city's total population.

Population Outside the Working Age: This classification refers to individuals who are not considered part of the labor force due to age constraints—specifically those aged 0–14 and those aged 65 and above. These individuals are typically excluded from employment statistics due to either not having reached or having surpassed the legal working age. In 2019, this group numbered approximately 93,718 individuals, constituting 46.16% of the city's overall population.

IV. Identify of heat island in city of M’sila:

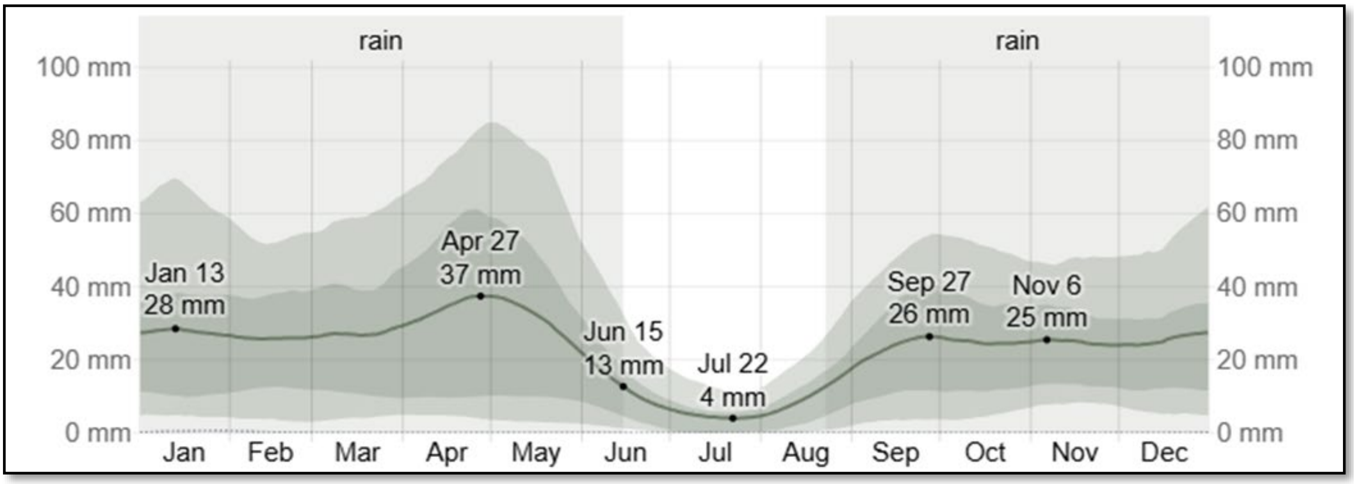
IV.1 Meteorological Data

Due to its geographical location, the climate of M’sila province which experiences a dry season from May to September and a wet season from October to April.

M’sila province is characterized by a semi-arid climate. Its climatic regime depends on two main parameters: precipitations and temperature

a. Precipitation:

The precipitation map serves as a crucial data source for analyzing the potential impacts of water availability and climatic conditions on urban development, water resource management, and agricultural activities in M’sila. When integrated with additional geographic and environmental variables such as (topography, vegetation cover, and existing infrastructure) it offers a comprehensive framework for informed planning and decision-making.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	28.0mm	25.8mm	26.8mm	34.4mm	32.3mm	12.5mm	4.3mm	9.6mm	24.0mm	24.4mm	25.2mm	25.1mm

Figure 12: Average Monthly Rainfall in M’sila (2024/2025), **(Weather Spark)**

The rainfall pattern observed during this period exhibits considerable variability on a monthly basis. Notably, April records the highest precipitation (34.4 mm), whereas July experiences the lowest, with only 4.3 mm of rainfall. When compared to the corresponding period in the previous year, the total precipitation from December to July is relatively higher. This indicates an irregular distribution of rainfall throughout the study period.

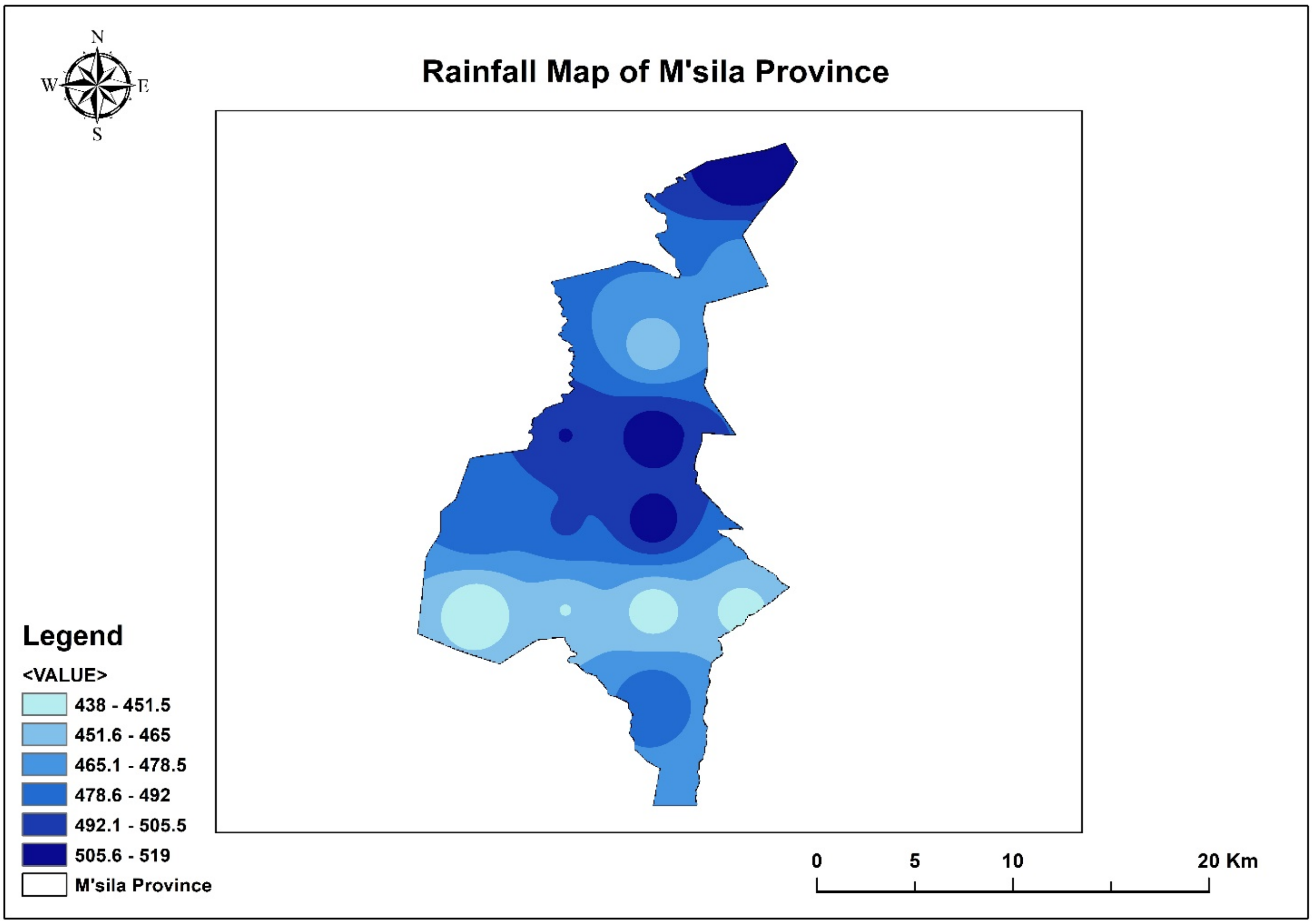
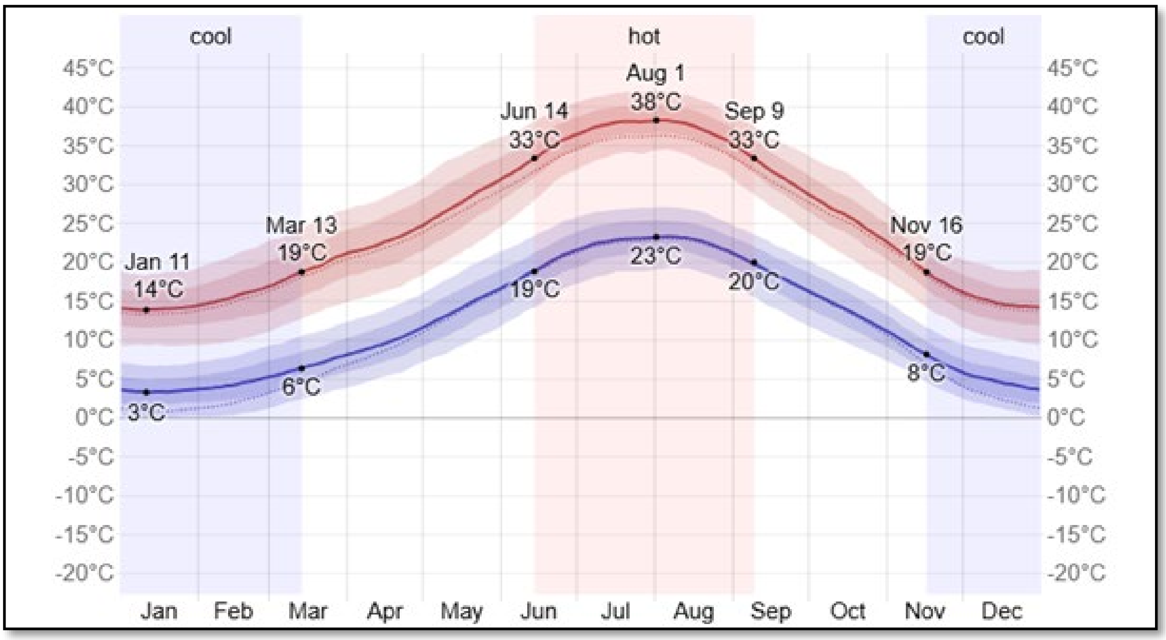
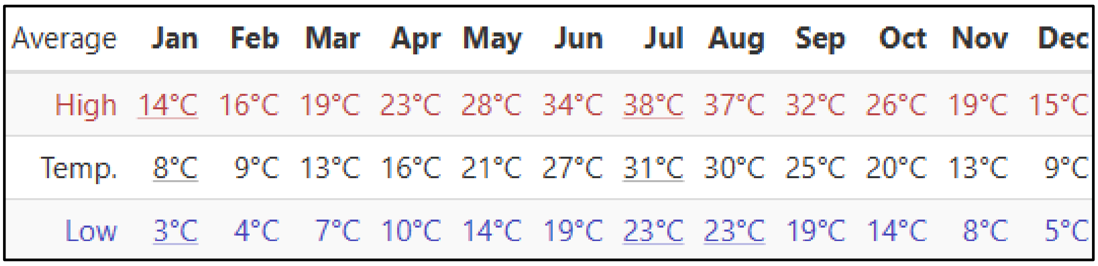


Figure 13: Rainfall map of M’sila province **(By the Author)**

b. Temperature:

The climatic data recorded by the meteorological station of M'sila during the period 2024/2025 shows that January and February are the coldest months with an average temperature of 3/4°C. July and August are the hottest months with an average temperature of 37/38°





Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	14°C	16°C	19°C	23°C	28°C	34°C	38°C	37°C	32°C	26°C	19°C	15°C
Temp.	8°C	9°C	13°C	16°C	21°C	27°C	31°C	30°C	25°C	20°C	13°C	9°C
Low	3°C	4°C	7°C	10°C	14°C	19°C	23°C	23°C	19°C	14°C	8°C	5°C

Figure 14: Average High and Low Temperature in M'sila (2024/2025) **(Weather Spark)**

b.1 Land Surface Temperature

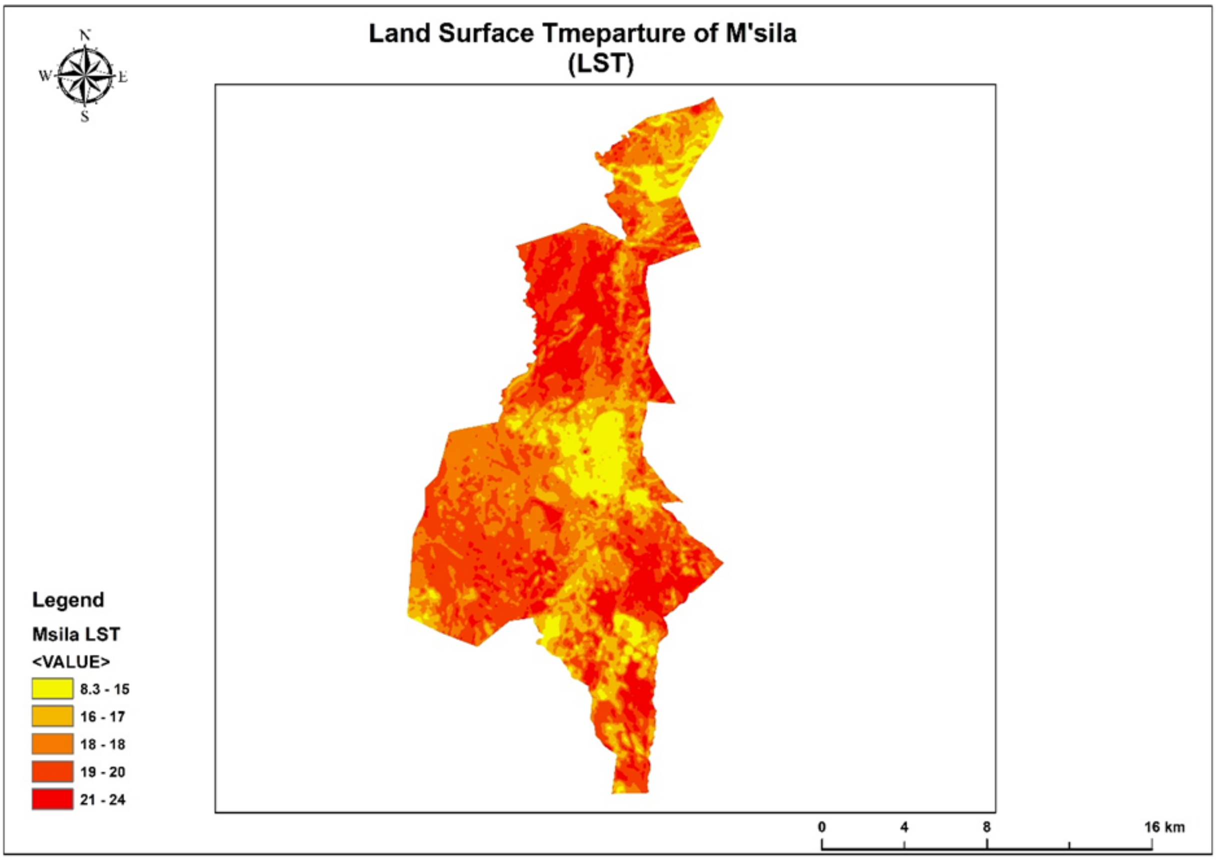


Figure 15: Land surface temperature pf M’sila province

(By the Author)

The map shows a clear gradient from lower temperatures in some peripheral areas (yellow in the central) to higher temperatures (orange and red) degree in the Northern and southern regions.

M’sila is positioned within the medium to high temperature zone combination between (Red /orange), suggesting that it experiences relatively warm to hot conditions compared to the surrounding areas.

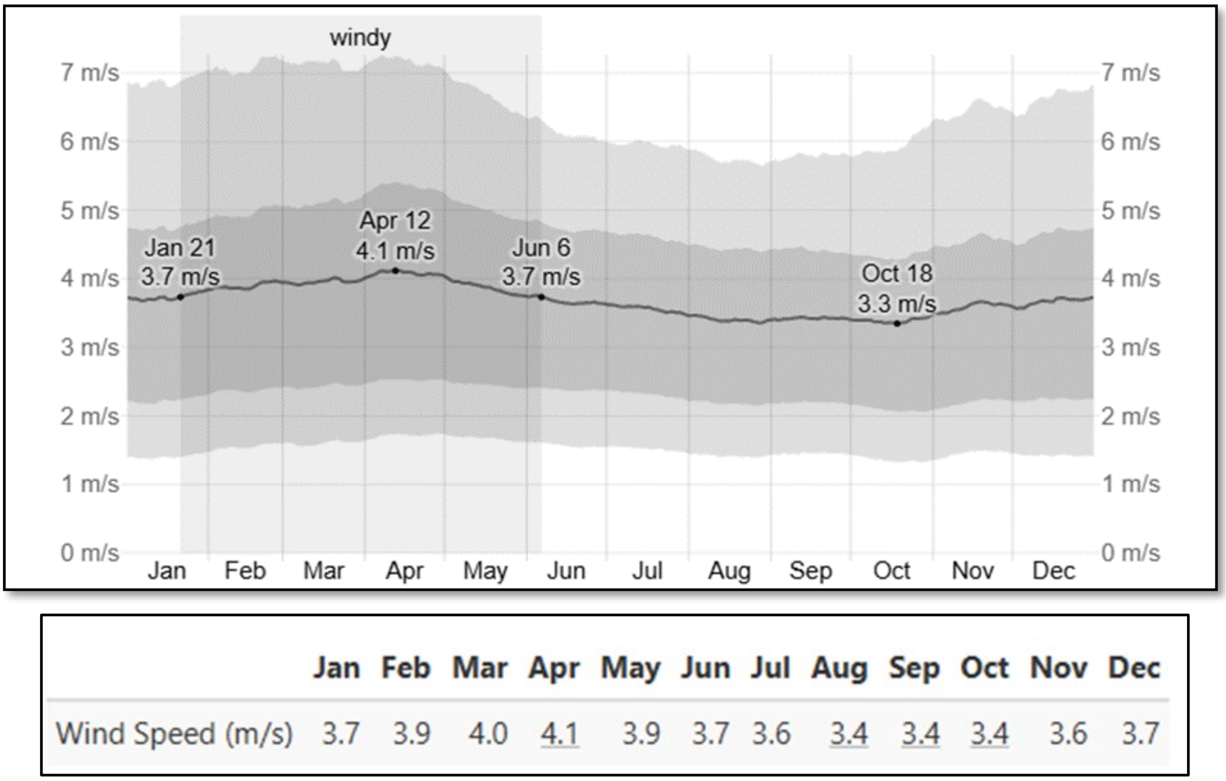
The red and dark orange zones, especially in the vicinity of M'sila, may suggest the presence of an Urban Heat Island (UHI) effect. This effect arises when urban environments, dominated by materials such as concrete and asphalt, absorb and retain heat, resulting in elevated temperatures compared to nearby rural regions.

The UHI phenomenon can intensify urban heat levels, leading to increased energy consumption for cooling purposes and posing potential risks to public health, particularly.

c. wind

The wind speed in M’sila shows a mild seasonal variation throughout the year. During the windier period, which spans 5 months from December to May, the average wind speeds exceed 3.9 meters per second.
The month of April experiences the highest average hourly wind speed of 4.1 meters per second.

On the other hand, the calmer time of year extends for 7 months, starting from May and ending on December. During this period, the average hourly wind speed drops, with August being the calmest month at an average of 3.4 meters per second.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed (m/s)	3.7	3.9	4.0	4.1	3.9	3.7	3.6	3.4	3.4	3.4	3.6	3.7

Figure 16: Average Wind Speed in M’sila (2024/2025) **(Weather Spark)**

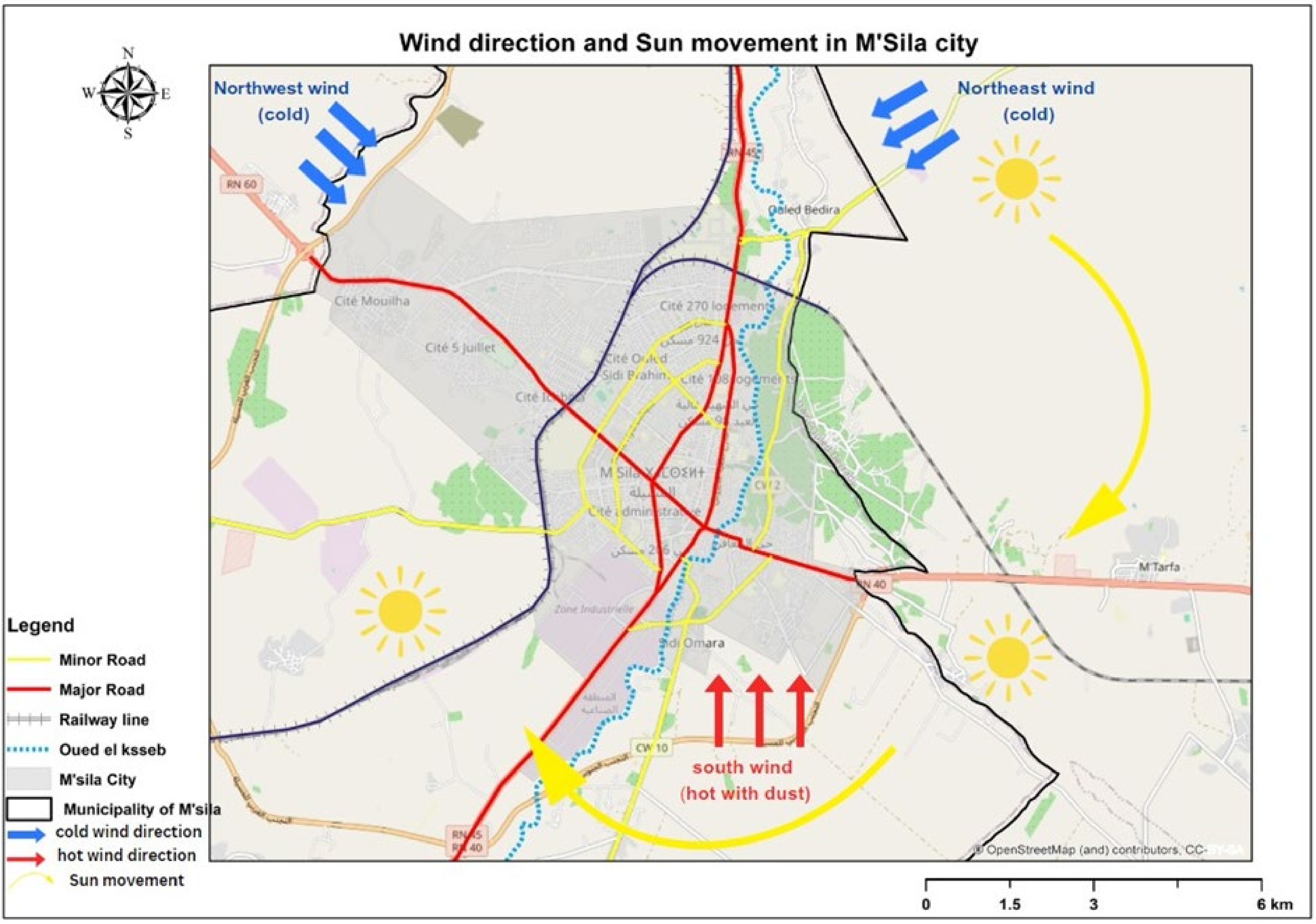


Figure 17: Wind direction and sun movement in M'sila city **(By the Author)**

V. Remote Sensing Data:

a. slope

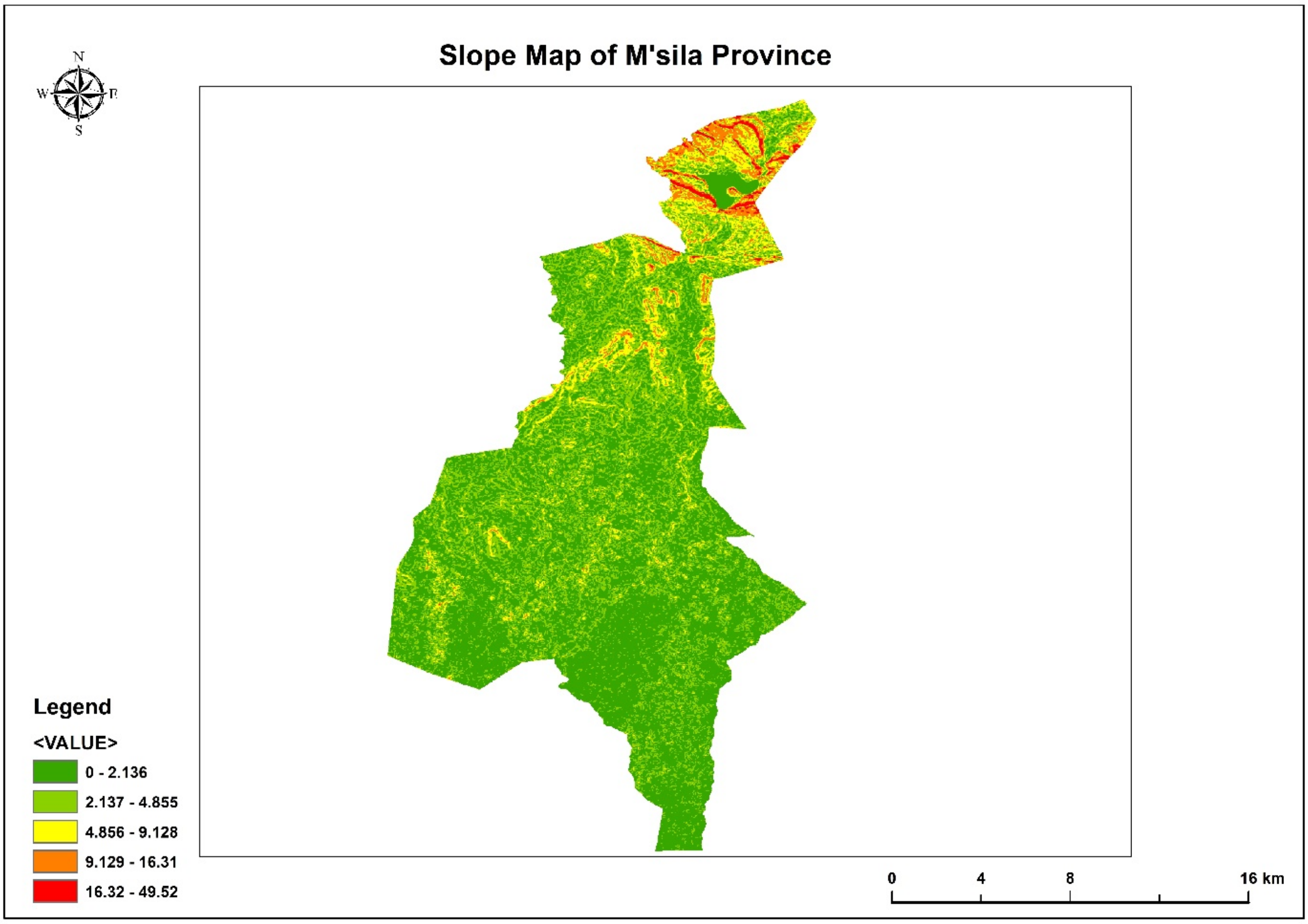


Figure 18: Slop map of M'sila province **(By the Author)**

Urban Heat Island (UHI) in Flat Urban Areas:

Urban centers such as M'sila, located in relatively flat terrains, are more susceptible to the Urban Heat Island effect. This vulnerability stems from the concentration of heat in densely built environments, particularly in areas with limited vegetation and extensive impervious surfaces such as concrete and asphalt. The flat topography also tends to retain heat, resulting in elevated land surface temperatures (LST) during the day and slower nocturnal cooling.

Heat Dissipation in Steeper Slope Areas:

In contrast, the northern and southwestern regions characterized by steeper

slopes are generally less urbanized and often maintain higher levels of natural vegetation, which contributes to environmental cooling. Moreover, the sloped terrain enhances air circulation, promoting more efficient heat dissipation compared to flatter urban zones.

Urban Expansion and Thermal Retention:

The flat topography of M’sila provides favorable conditions for urban expansion however, it also contributes to elevated land surface temperatures (LST) due to dense construction and a lack of natural cooling elements. These conditions intensify the Urban Heat Island (UHI) effect, especially during periods of intense solar radiation and minimal wind activity.

From an urban planning perspective, it is essential to implement strategies that mitigate heat accumulation in flat urban environments. These include incorporating green infrastructure, enhancing tree canopy coverage, and utilizing reflective or high-albedo materials in construction to reduce surface heat absorption.

Limited Wind Activity and Thermal Accumulation:

In regions like M’sila characterized by low wind speeds, reduced air circulation hinders the dispersion of heat, leading to thermal buildup within urban settings. This limited ventilation significantly contributes to the Urban Heat Island (UHI) effect, as it restricts the removal of accumulated heat (particularly during nighttime) resulting in sustained elevated land surface temperatures (LST).

VI. Land use & Land cover

a. Built-Up Zones (Red Areas):

The most prominent red regions on the map correspond to urbanized or built-up areas within M'sila. These urban zones are key contributors to the Urban Heat Island (UHI) effect, primarily due to the prevalence of heat-retaining materials such as concrete, asphalt, and dense building structures. These surfaces absorb substantial heat during daylight hours and release it gradually at night, leading to elevated Land Surface Temperatures (LST).

In M'sila, built-up areas are predominantly concentrated in the central part of the region, highlighting zones where the UHI effect is likely to be most intense. As urban expansion continues, these areas are expected to experience further increases in local temperatures, with implications for thermal comfort, public health, and energy consumption.

b. Agricultural Land (Yellow Areas):

The yellow-colored zones on the map denote cultivated agricultural areas, primarily situated in the northern and southeastern regions. The thermal influence of these zones varies depending on crop type and density. Densely planted crops with high evapotranspiration rates can contribute to localized cooling of the surrounding environment, while sparsely planted or recently harvested fields may result in slightly elevated surface temperatures.

Although the cooling influence of agricultural land can help moderate temperatures and counterbalance heat from nearby urban zones, this effect tends to be limited in spatial extent and primarily localized.

c. Vegetation and trees cover (Light Green Zones):

The green zones indicate vegetate areas with (tree cover), which is essential for mitigating the UHI effect.
Both vegetation and Trees play a critical role in "cooling urban environments" through shading and evapotranspiration, reducing both air and surface temperatures. The limited green areas on the map suggest that M'sila's urban environment lacks significant tree cover, particularly in the central and southern built-up areas where UHI effects are strongest.

Increasing vegetation and tree cover within and around urban zones would be a key strategy in mitigating the UHI effect by creating cooler microclimates, improving air quality, and lowering overall LST.

d. Water areas (Blue zones):

These areas represent likely wetlands or regions with temporary water cover. These regions generally exhibit lower temperatures as a result of nearby water bodies, which cool the surrounding atmosphere through the process of evaporation. Such areas function as natural thermal buffers, contributing to localized temperature reduction and enhancing microclimatic conditions in their vicinity.

e. Implications for Urban Heat Island (UHI) and Land Surface Temperature (LST):

e.1 UHI Effect in Built Areas:

The dense clustering of built-up areas in M'sila, with minimal integration of green spaces, intensifies the Urban Heat Island (UHI) effect, resulting in elevated urban temperatures relative to adjacent rural zones. This thermal disparity contributes to reduced thermal comfort, heightened energy demands for cooling, and increased public health vulnerabilities.

As urban expansion continues, maintaining a balance between infrastructure development and the preservation of natural land cover will be essential for mitigating the UHI effect and promoting sustainable urban living.

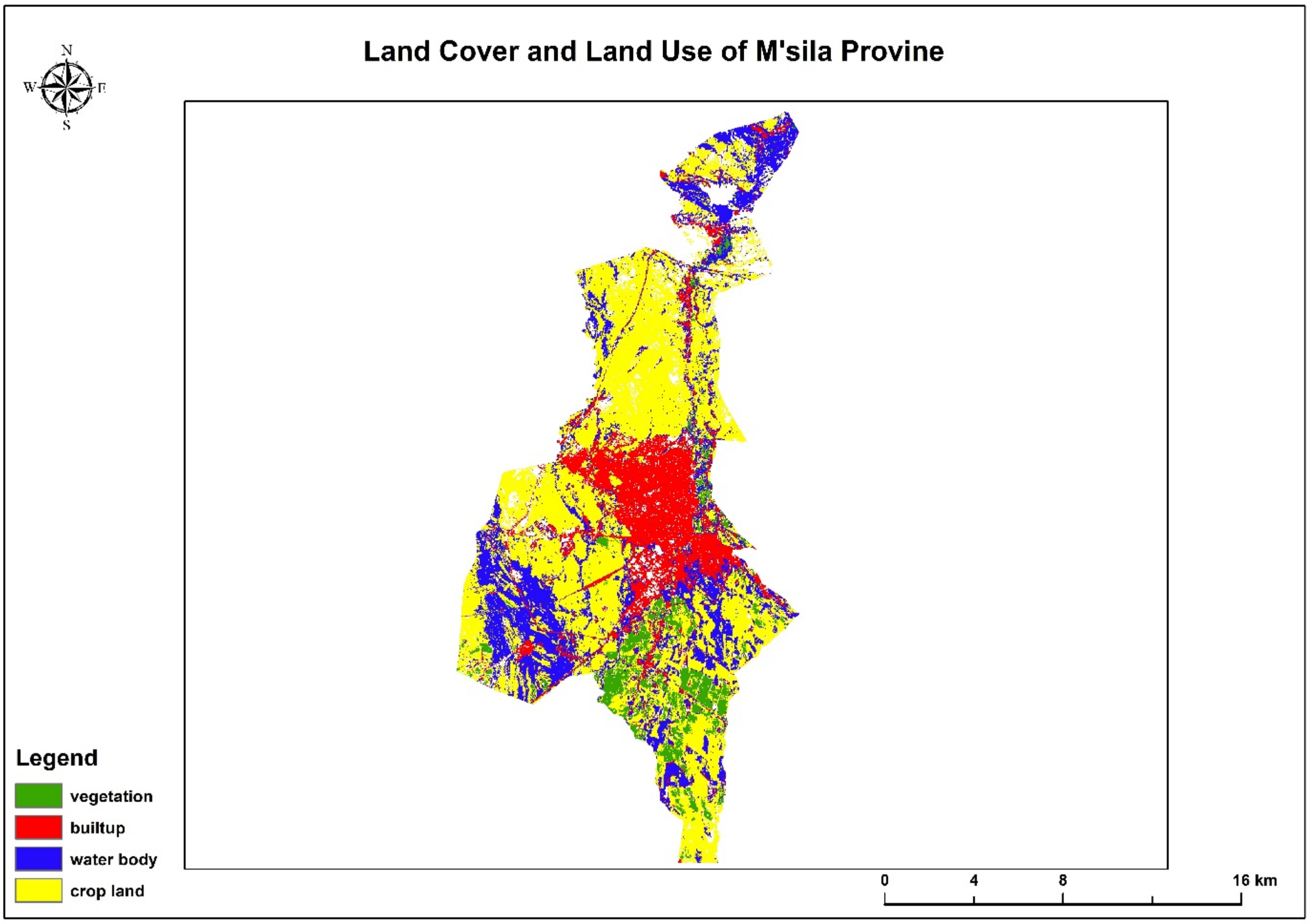


Figure 19: Land cover and Land use of M'sila province **(By the Author)**

VII. NDVI and Vegetation:

a. NDVI and Vegetation Distribution:

The map displays spatial variations in NDVI (Normalized Difference Vegetation Index) values, where darker green tones signify higher NDVI, representing denser and healthier vegetation, while lighter shades indicate sparser vegetation cover.

High NDVI Zones are primarily concentrated in the northeastern region, where dense vegetation contributes to effective cooling through evapotranspiration, a process by which plants release moisture into the atmosphere, thereby reducing local temperatures.

Low NDVI Zones, predominantly in the southwest, exhibit limited vegetation coverage. These areas tend to have elevated Land Surface Temperatures (LST) due to reduced evapotranspiration and increased exposure of bare surfaces to solar radiation.

b. Vegetation's Influence on UHI and LST:

Vegetative Cooling Effect: Areas with high NDVI serve as natural cooling zones, helping to mitigate the Urban Heat Island (UHI) effect by offering shade and enhancing evaporative cooling. In M'sila, these areas are associated with lower LST, which can help reduce heat buildup in nearby urban zones.

Sparse Vegetation and Heat Retention: In contrast, zones with lower NDVI values provide minimal cooling. The lack of vegetative cover leads to increased heat absorption, intensifying the UHI effect, particularly in built-up environments.

c. Vegetation in Urban and Peri-Urban Areas:

Urban Greening: While the map focuses on broader vegetation patterns, integrating green infrastructure within urban settings—such as trees, parks, and gardens—is vital for addressing UHI in cities like M’sila. Enhancing urban NDVI values through green spaces can improve thermal comfort and environmental quality.

Peri-Urban Agriculture: Agricultural zones at the urban periphery further support thermal regulation by increasing NDVI values in transitional areas. These zones function as climatic buffers, mitigating the inflow of heat into the urban core.

d. Seasonality and Vegetation Health:

Seasonal NDVI Fluctuations: In semi-arid environments like M’sila, NDVI values fluctuate seasonally based on rainfall and agricultural cycles. During dry periods or droughts, vegetation density decreases, diminishing the cooling effect and potentially leading to higher LST.

Sustainable Water Use: To maintain consistent NDVI values and support the vegetation’s cooling role, effective water resource management and sustainable irrigation practices are essential throughout the year.

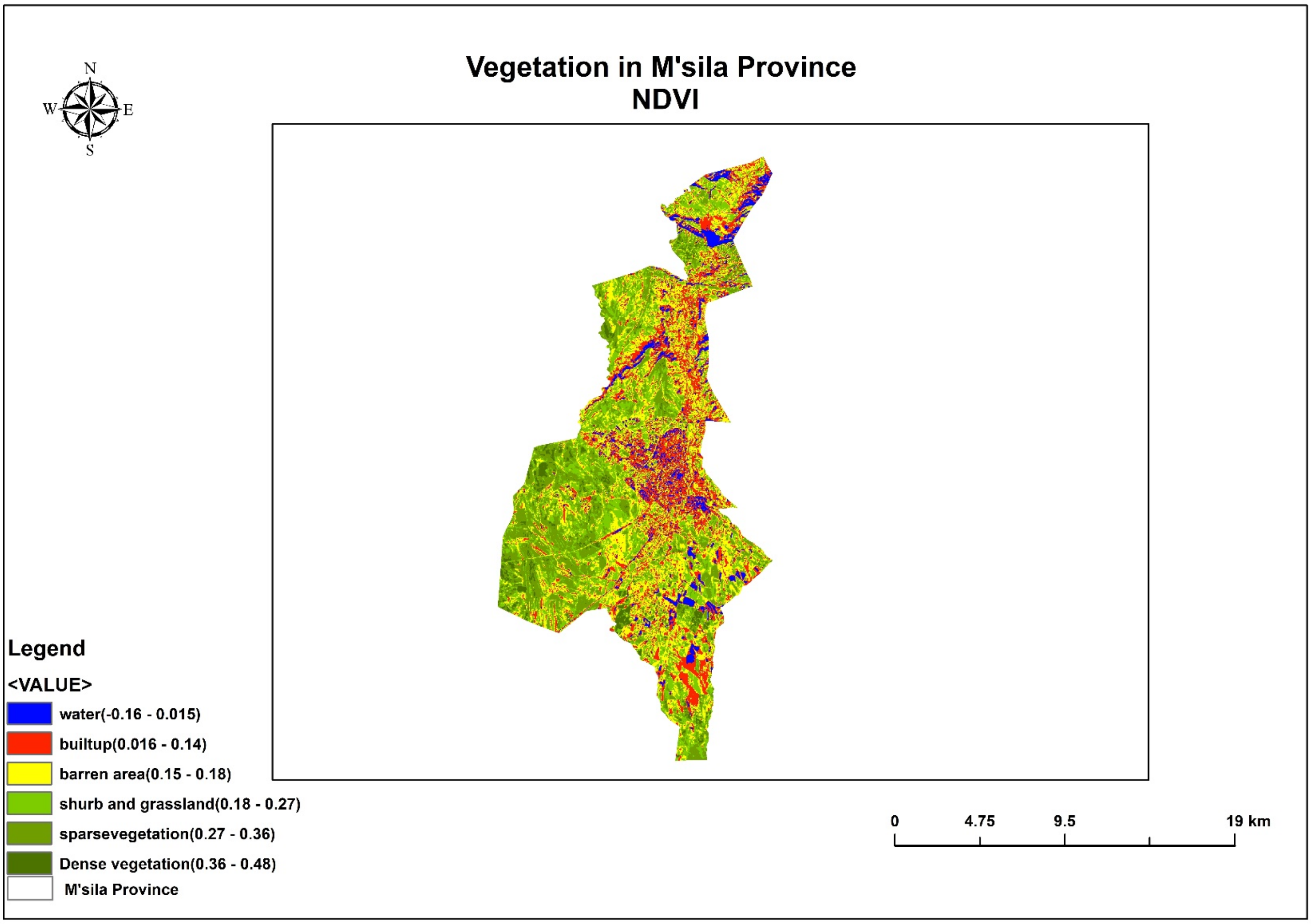


Figure 20: NDVI map in M’sila city province **(By the Author)**

The NDVI map of M’sila reveals a varied distribution of vegetation density, with higher concentrations of vegetation in the northeastern regions offering notable cooling effects, while the less vegetated southern areas are likely associated with elevated temperatures. In relation to the Urban Heat Island (UHI) effect and Land Surface Temperature (LST), expanding vegetation coverage both within the city and in its surrounding areas presents a practical and effective approach to mitigating heat accumulation and improving overall thermal comfort.

VIII. Impacts of Urban Heat Island Effect

The Urban Heat Island (UHI) effect poses significant challenges to urban environments, affecting human health, infrastructure, and the natural ecosystem.

Table 09: Impacts of Urban Heat Island Effect on the city

Impact Area	Description
Public Health	**Increased heat-related illnesses and mortality, especially among vulnerable groups.**
Air Quality	**Formation of smog and ground-level ozone; worsens asthma and respiratory diseases.**
Energy Demand	**Higher electricity uses for air conditioning; strain on power grids.**
Infrastructure Stress	**Roads, rail lines, and buildings deteriorate faster due to thermal expansion.**
Ecosystem & Biodiversity	**Tree stress, habitat loss, and species migration or death.**
Economic Losses	**Increased healthcare and energy costs; reduced worker productivity**

Conclusion:

In summary, this study has undertaken a comprehensive examination of the complex interrelationship between the urban heat island (UHI) phenomenon and the city of M’sila. By considering critical variables such as climatic conditions, patterns of land use and land cover including (vegetation density and population distribution) as well as the types of materials used in urban construction, the research has provided a nuanced understanding of the factors contributing to UHI in the municipal context.

The analysis has underscored the significant role these elements play in shaping both the physical structure and spatial organization of the urban landscape. Moreover, it has clarified the interconnected dynamics between these contributing factors and the intensification of the urban heat island effect. In doing so, the study contributes valuable insights into how urban form, materiality, and environmental context collectively influence thermal conditions in rapidly developing urban areas like M’sila.

Case Study

Introduction:

The selection of the 500 Housing Units Neighborhood as a case study is driven by the analysis of the Land Surface Temperature (LST) map, which shows temperature variations across different urban zones. The neighborhood is located in the orange zone on the map, indicating areas with relatively high surface temperatures. This positioning suggests that the neighborhood is significantly impacted by the Urban Heat Island (UHI) effect, where urban areas experience higher temperatures than their rural surroundings due to the absorption and retention of heat by buildings, roads, and other infrastructure.

The high temperature recorded in this area makes it a prime location for assessing how urban design, land use, and construction materials contribute to the UHI effect. By focusing on this neighborhood, the study aims to gain insights into the thermal dynamics of densely populated areas and propose solutions for mitigating UHI effects through sustainable urban planning practices. The analysis of LST will allow for a clear understanding of the heat distribution within the neighborhood, helping to identify hotspots and areas requiring intervention.

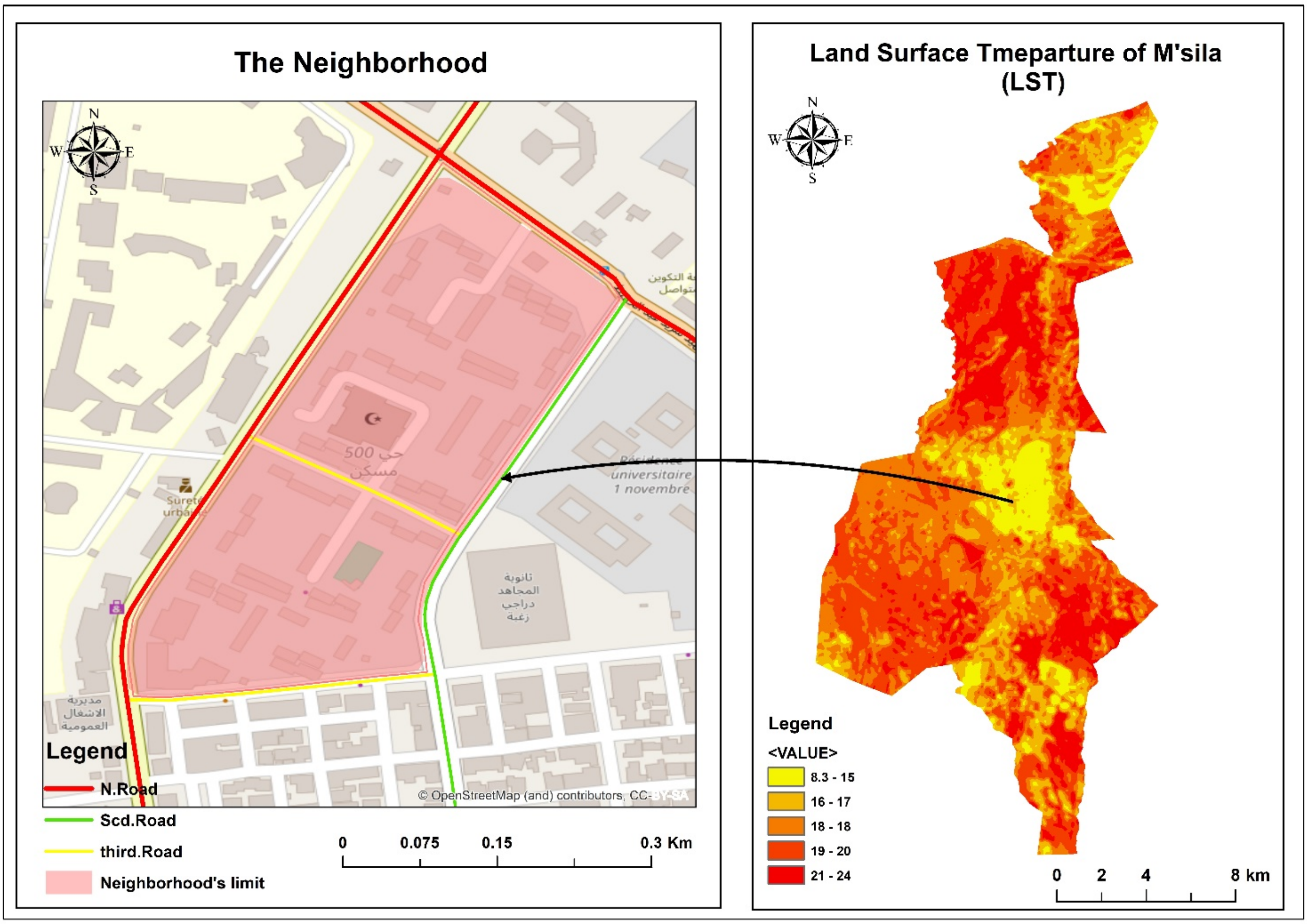


Figure 21: Spatial Location of the Neighborhood within the LST Map

(By the Author)

I. Location:

The 500 Housing Units Neighborhood is located in the northwest of the M'sila municipality, and it covers an area of approximately 93200 m^2 According to the topographic survey conducted in March 1992.

The neighborhood enjoys a strategic position within the urban fabric of the city, as it lies on the northern side, directly adjacent to the main road linking the city center to the Ichbilia neighborhood via National Road No.65. This positioning grants it high accessibility and enhances its urban significance. Moreover, on its western side, the neighborhood is bordered by the Provincial Road No.22(which connects the cities of Bou Saada and Bordj Bou Arreridj). Additionally, the neighborhood benefits from its central position among key facilities, most notably the university and its annexes, which significantly contribute to its functional importance within the urban context.

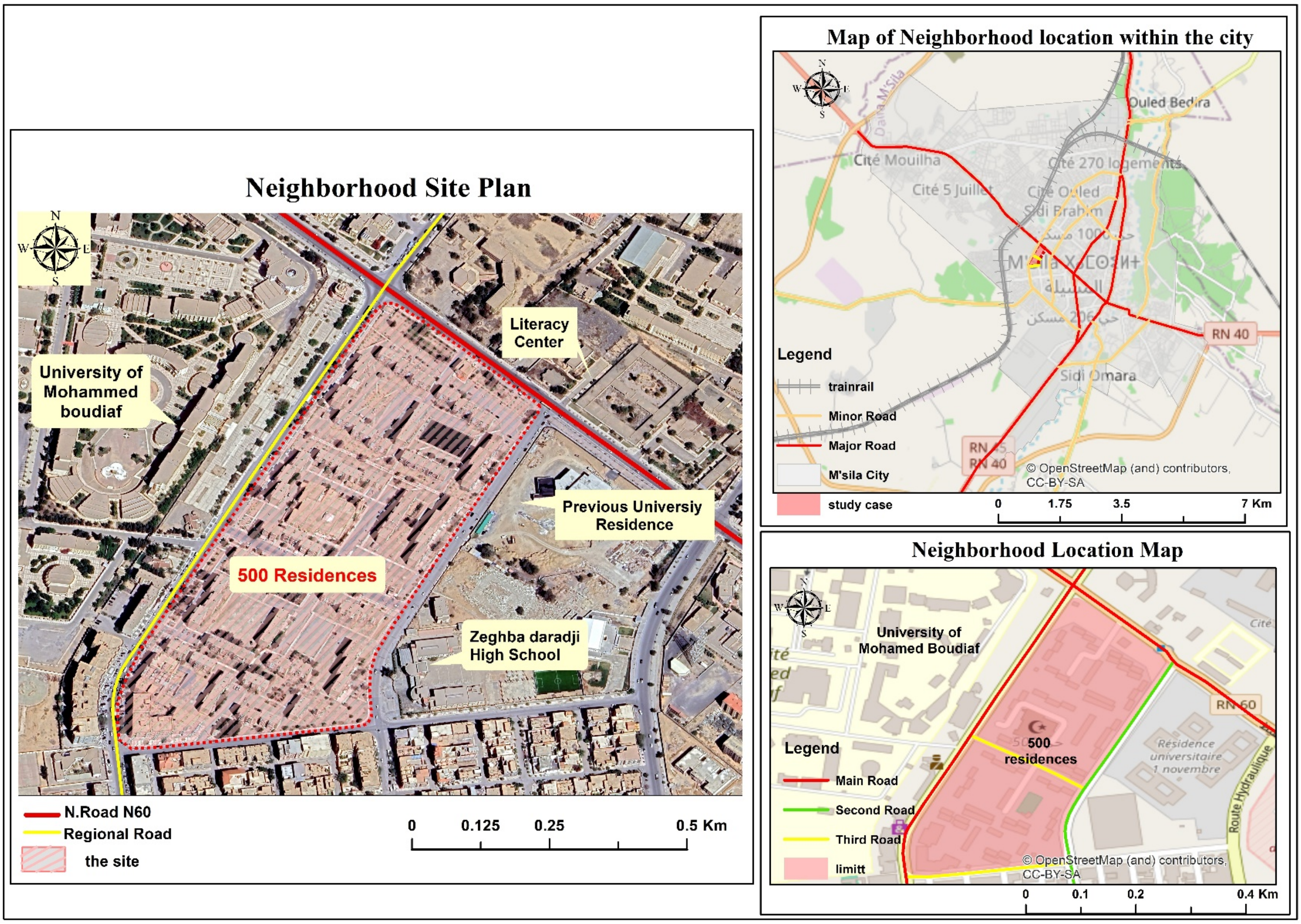


Figure 22: The neighborhood location **(By the Author)**

II. Density:

a. Spatial Composition of the Neighborhood:

The 500 Housing Neighborhood encompasses a total land area of 93,200 square meters. Within this area, built structures occupy approximately 13,154 square meters, representing 14.24% of the total surface. Conversely, the unbuilt space extends over 80,046 square meters, accounting for 85.76% of the overall area.

Table 10: Distribution of Neighborhood Land Areas

Category	Area (m²)	Percentage (%)
Built-up Area (Residential)	13,154	14.12
Unbuilt Area	79,000	84.76
Built-up Area (Non-Residential)	1,046	1.12
Total Land Area	93,200	100

Source: Annex of the Housing Promotion and Real Estate Management Office (OPGI)

This table illustrates the spatial distribution of land use within the neighborhood, highlighting the predominance of unbuilt spaces, followed by residential structures and a minor proportion allocated to non-residential built-up areas.

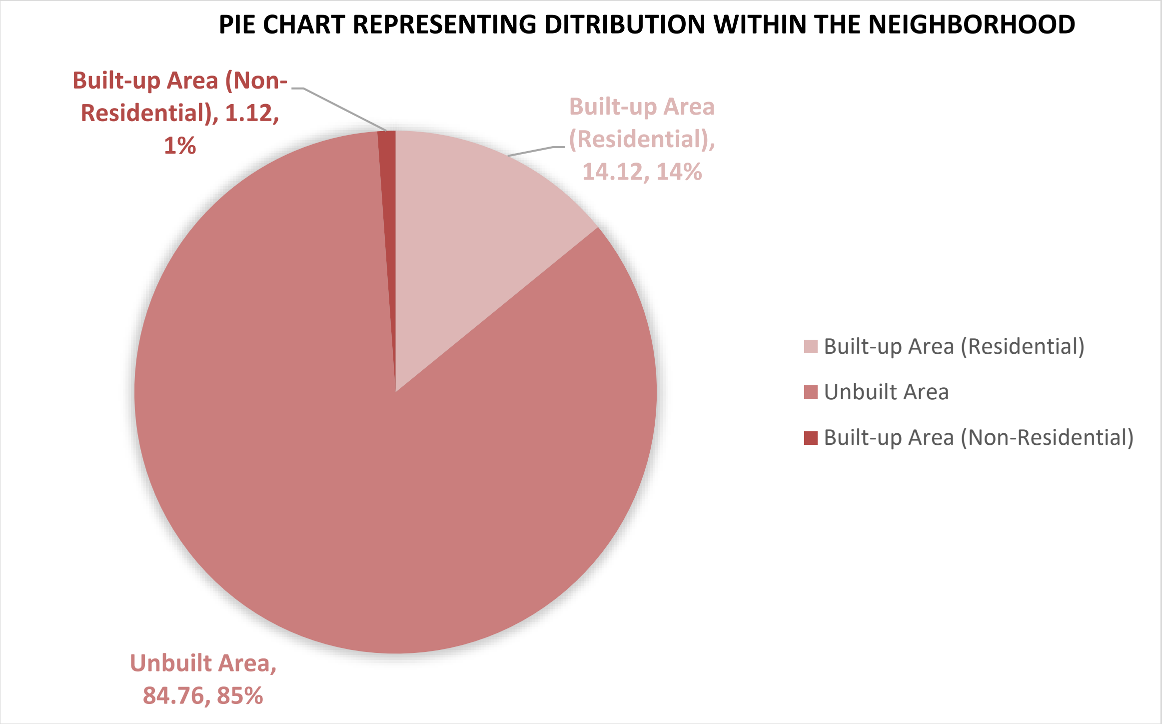


Figure 23: Site plan for the neighborhood **(By the Author)**

III. Built Environment and their Contribution to Heat Islands

a. Residential units:

A total of 500 housing units were developed through the construction of 65 apartment buildings, categorized into three distinct types. Of these, 50 buildings are equipped with commercial premises, accounting for 79.36% of the total building stock.

Table 11: Typology of Apartment Buildings in the 500 Housing Units Neighborhood

Type	Residential building	Number of floors	Number of housing units
a	15	R+3	104
b	48	C+4	348
c	2	C+3	12
Total	65	/	500

b. Services and Facilities:

The 500 Housing Units Neighborhood comprises a selection of functional facilities that support both residential life and daily urban activity. Among the primary services are a mosque and a group of commercial kiosks, collectively occupying an area of 1,046 m², which corresponds to approximately 1.12% of the total site area. Additionally, a local administrative branch of the Office for Promotion and Real Estate Management (OPGI) is located within the residential blocks and provides institutional support services to the neighborhood’s inhabitants. Beyond these designated facilities, the neighborhood benefits from a strategically advantageous location, situated directly across from the University of Mohammed Boudiaf.
This proximity to a major academic institution has stimulated the growth of a diverse range of private and semi-formal commercial activities, including fast food restaurants, cafés, stationery shops, printing services, and convenience stores.

The extensive use of air conditioning in commercial settings significantly alters the thermodynamic balance of urban environments, thereby contributing to increased local temperatures.

These establishments serve not only the neighborhood's residents but also the large population of students and university visitors, contributing to a lively urban atmosphere and positioning the neighborhood as a vibrant socio-economic node within the broader urban fabric. The dynamic interaction between residential occupancy and surrounding institutional influence has shaped the neighborhood into a multifunctional urban space, where formal and organic services coexist in response to spatial demand and pedestrian activity.

Figure 24: facilities in 500-unit neighborhood **(By the Author)**

IV. The Role of Urban Design and Residential Practices in Enhancing Urban Heat Islands

a. Use of air conditioners:

As part of a field study conducted in the “500 Housing” neighborhood, it was found that the extensive use of air conditioners is among the key contributors to the increase in local temperatures and the intensification of the Urban Heat Island (UHI) effect. Air conditioners, by transferring heat from indoor spaces to the outdoors, release substantial amounts of waste heat into the surrounding environment. Assuming each residential unit is equipped with at least one air conditioner, the neighborhood hosts the operation of approximately 500 household air conditioning units, not including additional units installed in commercial shops and small-scale businesses throughout the area.

These thermal emissions contribute directly to raising ambient air temperatures, particularly during evening and nighttime hours when wind movement is limited and natural ventilation is reduced. Field observations revealed a noticeable temperature difference between the neighborhood and its surrounding rural or less densely built-up areas.

This negative impact is exacerbated when the heat discharged by air conditioners combines with the heat retained in asphalt and concrete surfaces, which are characteristic of the neighborhood's infrastructure. This leads to greater nighttime heat accumulation and delayed cooling, a hallmark of urban heat islands. Moreover, this triggers a self-reinforcing cycle: the hotter the outdoor environment becomes, the more residents rely on air conditioning, thereby increasing heat emissions further.

b. Urban Ventilation (air flow) and Typo-Morphology

Urban typo-morphology "referring to the layout, form, and structure of urban environments "plays a vital role in shaping local wind patterns and enhancing urban ventilation. By influencing air flow, street orientation, and building arrangement, urban morphology can serve as a passive strategy to reduce heat stress and mitigate the urban heat island effect.

In our neighborhood the most of buildings are in the right orientation which means it’s not the only factor here.

Figure 25: Spatial Distribution of Airflow and Prevailing Wind Directions

(By the Author)

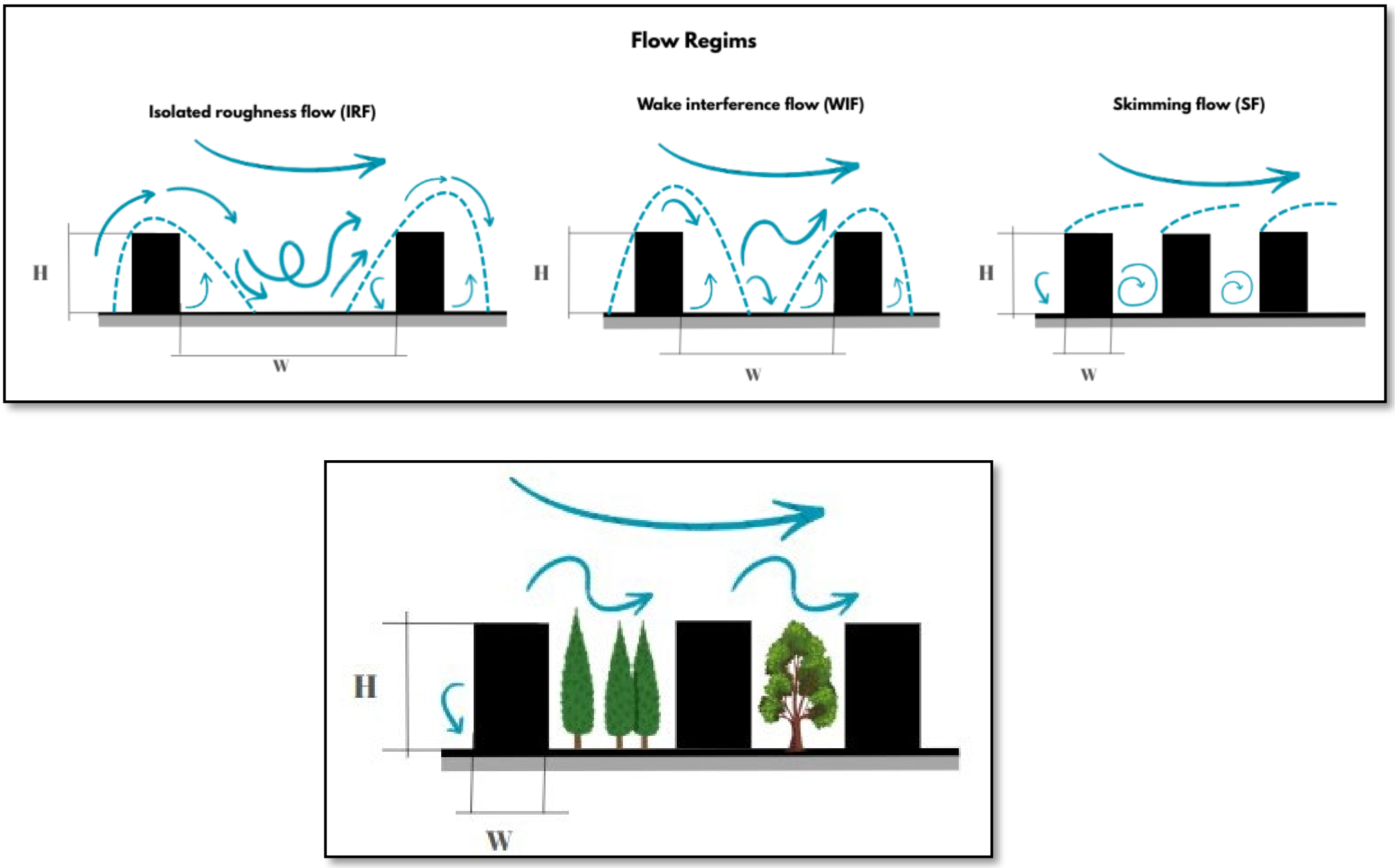


Figure 26: Flow regimes in the neighborhood **(By the Author)**

Urban ventilation is significantly influenced by spatial parameters such as building spacing, street width, and the distance between built structures.

As the typo-morphological layout becomes denser, airflow is often obstructed, leading to heat accumulation and reduced thermal comfort. As the distance between buildings decreases, wind exposure tends to diminish; conversely.

This relationship highlights the importance of incorporating adequate spacing and orientation strategies within urban design to enhance environmental performance

c. Elevation:

In the 500 Housing Units Neighborhood, the average building elevation reaches approximately 15.40 meters, corresponding to mid-rise structures of 5 to 6 stories. This verticality plays a significant role in shaping the local microclimate and intensifying the Urban Heat Island (UHI) effect. Taller buildings exhibit a greater surface-to-volume ratio, particularly on vertical façades and rooftops, which leads to increased solar heat absorption and thermal storage throughout the day.

The urban morphology formed by these elevations also affects airflow dynamics. In areas with narrow street canyons, the height of buildings obstructs horizontal wind movement, reducing natural ventilation and increasing heat entrapment at pedestrian level. This stagnation of air can lead to thermal stratification, especially in densely built blocks, where convective cooling is limited.

Moreover, while building height can produce beneficial shading effects, these are often unevenly distributed. Shaded zones between buildings may experience cooler temperatures during the day, but sun-exposed surfaces (especially rooftops and upper façades) can reach significantly higher thermal loads. This differential creates a patchy thermal landscape that contributes to the overall complexity of the UHI effect within the neighborhood.

This elevation in this context is a double-edged climatic factor: while it modifies solar exposure and wind behavior, it also amplifies urban heat retention in the absence of mitigating strategies such as reflective materials, green roofs, or ventilated corridors.

We also discuss the Sky View Factor, which is the proportion of the sky visible from a point on the ground. This factor is important in determining nocturnal heat loss, as a greater view of the sky can enhance radiative cooling at night. A key driver of the Urban Heat Island.

d. Construction materials and color:

In the residential developments of 500 unit, the primary building materials include reinforced concrete, red clay bricks, cement blocks, and plaster finishes. These materials are commonly chosen for their durability, cost-effectiveness, and availability, but they contribute significantly to the urban heat island (UHI) effect due to their inherent physical properties.

Reinforced concrete, which is the main structural element in many multi-story buildings, has a high thermal mass, meaning it absorbs and retains significant amounts of heat during the day. This heat is gradually released during the night, raising nighttime temperatures in urban areas. While concrete is structurally efficient, its thermal retention exacerbates the UHI effect in densely built environments like 500-unit neighborhood.

Red clay bricks are another predominant building material used for non-load-bearing walls in this residential units. Like concrete, red clay bricks also possess high thermal mass, which leads to the accumulation of heat during the day. However, they are slightly more porous than concrete, which can result in better moisture regulation but still contribute to thermal inertia in the building envelope.

Cement blocks are widely utilized in both load-bearing and non-load-bearing walls. Although lighter than red clay bricks and concrete, cement blocks also store heat and contribute to increased indoor temperatures, especially in the absence of adequate thermal insulation. These materials are typically used in combination with plaster finishes, which, while offering a smooth aesthetic, do little to reduce thermal heat gain.

Furthermore, the lack of thermal insulation in the majority of buildings within 500-unit neighborhood exacerbates the situation. Without proper insulation in walls, roofs, or windows, buildings fail to reduce heat transfer, leading to higher cooling energy demand and increased temperatures within living spaces.

These materials, due to their heat retention characteristics, play a critical role in enhancing the urban heat island effect in this Neighborhood. As such, addressing the material choices and exploring alternatives, such as insulated concrete panels, lightweight cladding, or eco-friendly building materials with lower thermal mass, could significantly mitigate the urban heat accumulation in the area.

In addition to the thermal properties of the materials themselves, the external color palette of buildings significantly influences surface temperature dynamics. A large portion of 500 unit building facades and rooftops are finished in medium to dark tones, such as beige, or brown, which exhibit low albedo values and therefore absorb a significant amount of solar radiation. These low-reflectivity surfaces accelerate heat retention on façades and rooftops, intensifying the UHI effect, especially in summer. In contrast, areas or buildings with lighter-colored finishes, though less common, demonstrate lower surface temperatures due to their higher solar reflectance, offering a modest mitigation effect.

Together, the choice of construction materials and surface colors in this urban district reflects a thermal profile that is largely unsuitable for hot, Mediterranean

climates. Without the integration of cool materials, reflective coatings, or passive design strategies, the neighborhood remains highly susceptible to urban overheating. This underscores the importance of adopting climate-responsive architecture and material innovation in future urban planning and retrofitting efforts in Algerian cities.

Figure 27: Construction materials and color of the building in the neighborhood

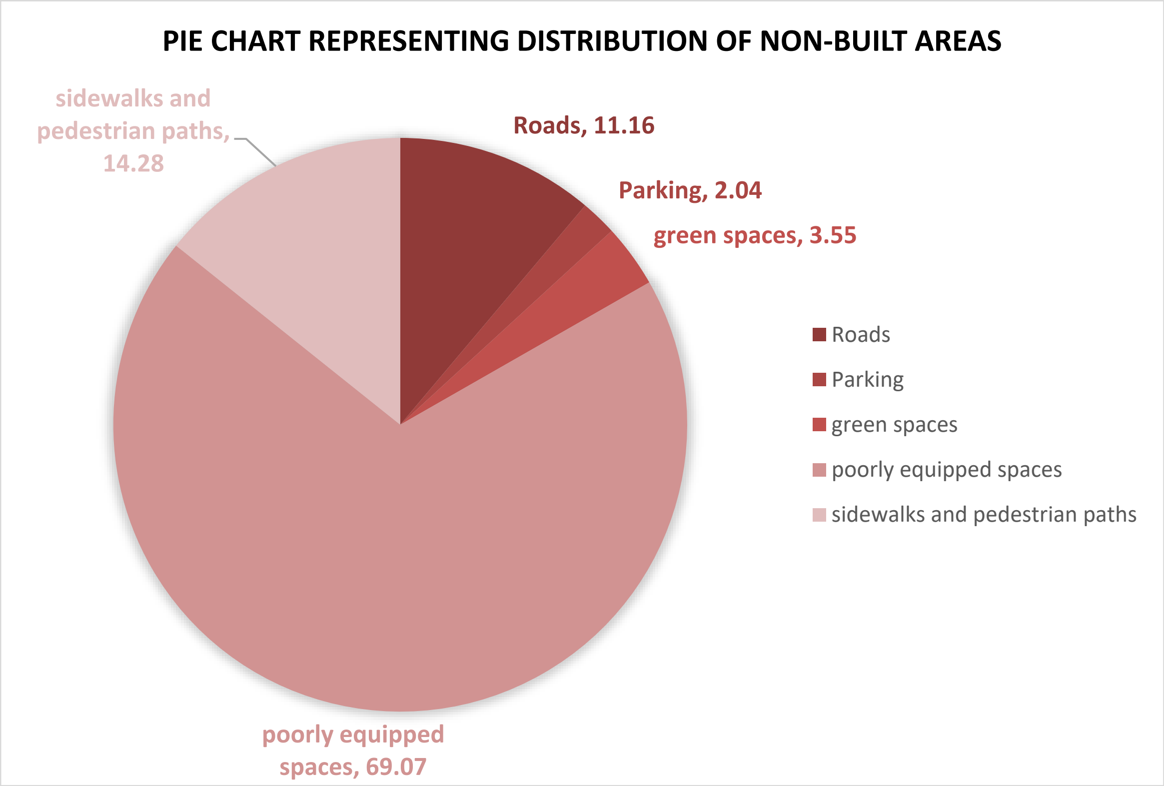
(By the Author)

V. Non-built space:

The built-up area occupies 15.24% of the total site, leaving a significant portion 84.76% as non-built spaces. These areas include various types of urban open spaces, although they are generally degraded and poorly developed.

Table 12: Distribution of Non-Built Areas

Designation	Area (m^2)	Percentage (%)
Roads	8820	11.16
Parking	1612.5	2.04
Green spaces	2800	3.55
Poorly equipped space	54563.5	69.07
Sidewalks and pedestrian paths	11204	14.18
Total	79,000	100



a. Green Infrastructure

Green infrastructure (GI) and Tree canopies play a crucial role in urban environments, influencing not only ecological sustainability but also the psychological well-being of residents, urban aesthetics, and microclimate regulation through two primary mechanisms: solar radiation interception and evapotranspiration.

Research has shown that access to green spaces such as parks, tree-lined streets, and gardens contributes significantly to mental health by offering restorative environments that reduce stress and promote relaxation . These natural settings allow individuals to recover from mental fatigue and have been linked to lower rates of anxiety and depression.

In addition to psychological benefits, green infrastructure enhances the visual and cultural character of neighborhoods. It contributes to the beauty of urban spaces by introducing natural variation, seasonal aesthetics, and culturally meaningful landmarks, thereby fostering a sense of place and community identity. Furthermore, GI serves a critical environmental function by mitigating the UHI effect, which causes elevated temperatures in built environments. Vegetation lowers ambient and surface temperatures through shading and evapotranspiration, improving thermal comfort and reducing the need for artificial cooling. These climate-regulating functions of green infrastructure are essential in adapting cities to climate change and enhancing urban resilience. Therefore, integrating green infrastructure in neighborhood design is not only beneficial for ecological sustainability but also essential for the mental and physical well-being of urban residents.

In the case of the 500 Housing Units Neighborhood, there is only one officially developed green area, established by the relevant authorities. It is located in the northern part of the neighborhood and is enclosed by a simple fence.

This green space covers an area of 2,800 m², representing just 3.55% of the total surface area (a figure that remains far below the national standard of 6.5 m² per resident). Moreover, some ground-floor residents have informally appropriated nearby open areas for personal or communal use. While technically unauthorized, such initiatives can be seen as a positive expression of community involvement, aligning with the participatory goals of sustainable development.

This element was not adequately considered in the planning of the 500 Housing Neighborhood, except through individual initiatives undertaken by residents.

Figure: 28 green infrastructures in 500-unit neighborhood

(By the Author)

An analysis of the site plan and photographic evidence reveals that green spaces within the neighborhood are insufficient relative to its overall area. Moreover, while certain areas have been designated for green space development, they remain unfortunately undeveloped and inadequately maintained.

b. Urban street scale geometry

Road infrastructure is a fundamental element in the spatial and functional organization of urban neighborhoods. Roads define movement patterns, shape the morphology of cities, and serve as primary connectors between residential, commercial, and public spaces. As such, the design, distribution, and material composition of road networks directly influence not only accessibility and mobility, but also the microclimatic conditions of urban areas.

Despite their functional necessity, roads are among the most extensive and impactful impervious surfaces in urban environments, contributing substantially to the phenomenon of urban heat islands (UHI).

The contribution of roads to the development of UHI is multifaceted, involving their physical characteristics, spatial distribution, and interaction with surrounding land uses.

The average building height (H) to street width (W) ratio, along with orientation:

The proportional relationship between street width and building height typically articulated as the height-to-width (H/W) ratio—constitutes a fundamental parameter in urban morphology, particularly in the context of solar access and energy performance. Variations in this ratio significantly modulate the degree of solar radiation incident on building façades and street-level surfaces. Consequently, optimizing the H/W ratio is essential for enhancing energy efficiency, controlling microclimatic conditions, and promoting thermal comfort within dense urban environments.

Table 13: The average building height (H) to street width (W) ratio, along with orientation **(By the Author)**

H/W Ratio	Orientation	Notes
0.23	N-S	Less effective shading
1.28	N-S	Improved shading
0.19	E-W	High Solar Exposure
0.61	E-W	Less effective shading

Height-to-Width (H/W) Ratios: Higher H/W ratios can provide increased shading, reducing surface temperatures and improving pedestrian comfort.

Street Orientation: North-South oriented streets tend to receive more uniform shading throughout the day, whereas East-West orientations may experience higher solar exposure during peak hours (Prioritize North-South Street orientations in new developments to maximize shading benefits).

Optimal H/W Ratios: Implementing H/W ratios between 2:1 and 3:1 can effectively reduce solar exposure on street levels, enhancing thermal comfort.

Vegetation and Green Spaces: Incorporate urban greenery to mitigate heat island effects and improve microclimatic conditions.

Use of Reflective Materials: Employ building materials with high albedo to reflect solar radiation and reduce heat absorption.

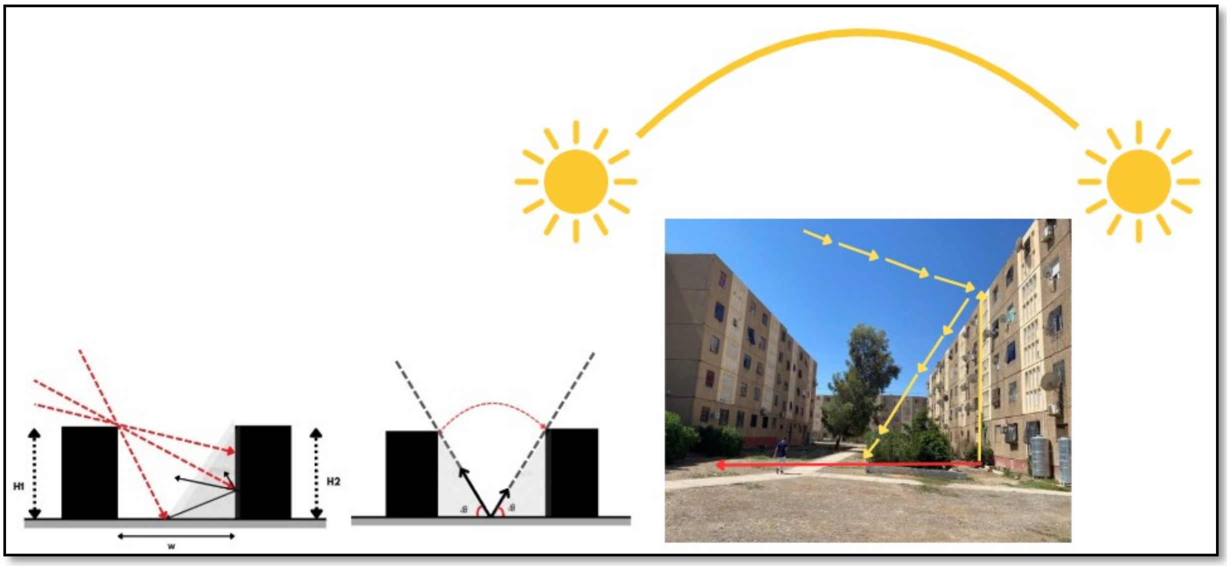


Figure 29: Sunlight Reflection Geometry on Building and Ground Surfaces of the neighborhood **(By the Author)**

c. Spatial Configuration and Urban Geometry:

The geometric configuration of roads and their relationship with surrounding built forms influence air movement, solar exposure, and heat retention. Wide roads flanked by tall buildings can create urban canyons that trap heat and delay nocturnal cooling. Additionally, road networks that maximize impervious coverage while minimizing green spaces exacerbate UHI intensity across cityscapes.

While roads are indispensable to urban function and organization, their thermal and environmental impacts cannot be overlooked. The material properties, spatial arrangements, and lack of vegetative integration associated with road infrastructure contribute significantly to the formation and persistence of urban heat islands. Therefore, incorporating climate-sensitive design strategies such as; the use of reflective pavements, increased street-level vegetation, and improved urban geometry (is crucial for creating more resilient and thermally balanced cities).

The internal road network of the neighborhood is structured around a primary central road, which is the most prominent and functionally significant route. This main road has a width of 8 meters and is currently in good condition, facilitating the majority of vehicular movement within the area. It is connected to a series of secondary roads that provide direct access to the surrounding apartment buildings. These secondary roads, also well maintained, typically have widths ranging between 5 and 6 meters and support local traffic circulation efficiently.

In the eastern and southern parts of the neighborhood, two additional secondary roads are present. These roads experience relatively low traffic volumes and have an average width of 10 meters. Despite reduced usage, they are in good structural condition and contribute to internal connectivity.

The neighborhood is surrounded on all sides by major arterial roads characterized by high traffic flow. Notably, the western boundary is defined by the main road

connecting M'Sila to Bousaada. This road is in excellent condition due to its central location within the city, the high volume of traffic it accommodates, and the consistent maintenance and improvements carried out by municipal authorities. Its strategic importance makes it a critical component of both local and regional mobility infrastructure.

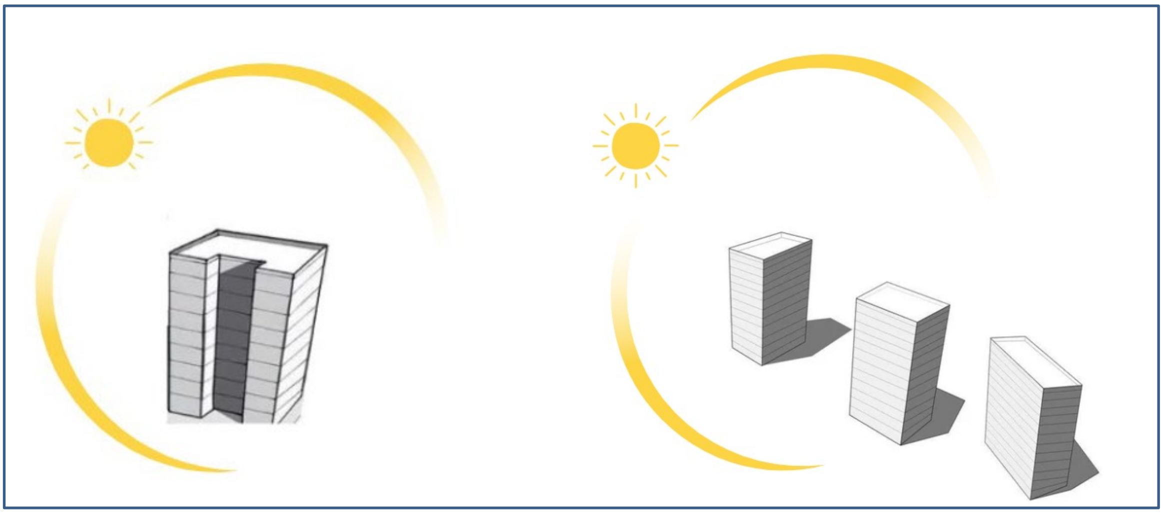


Figure 30: Representation of the spatial configuration and urban morphology present in the neighborhood **(By the Author)**

Several other key factors explain their influence on urban thermal dynamics:

d. Impervious Surface Materials and Thermal Properties

Urban roads are predominantly constructed using impervious materials such as asphalt and concrete. These materials are characterized by low albedo and high heat retention, absorbing and storing large amounts of solar radiation throughout the day. Asphalt, for instance, can reach surface temperatures exceeding 60°C (140°F), significantly elevating local ambient temperatures, especially in densely built-up areas. This absorption effect contributes to higher surface temperatures and reduced cooling at night.

e. Lack of Vegetative Cover

Most roadways lack sufficient vegetation or tree canopy, which is essential for cooling through shading and evapotranspiration. The absence of vegetative elements results in reduced natural heat mitigation and increased exposure to direct solar radiation. Urban studies have shown that tree-lined streets maintain significantly lower surface temperatures than those without vegetative buffers.

Figure 31: Surface Materials and Thermal Properties & Vegetative Cover in the neighborhood **(By the Author)**

f. Anthropogenic Heat Emissions from Traffic

Roads are major contributors to anthropogenic heat in urban environments, primarily due to vehicular traffic. Internal combustion engines release heat directly into the surrounding atmosphere, and processes such as idling, acceleration, and friction amplify local temperatures.

This effect becomes particularly intense in high-traffic corridors during peak hours, turning them into hotspots of heat accumulation.

Areas around traffic signals and bus stops are especially vulnerable due to the frequent stop-and-go patterns. When vehicles stop, restart, or accelerate again, they consume more fuel, leading to higher emissions of both heat and greenhouse gases such as CO_2 and NO_x. Moreover, traffic congestion near these points increases the concentration of thermal pollutants in the air. Additionally, the pavement (typically asphalt) acts as a heat reservoir, absorbing solar radiation during the day and re-emitting it at night.

This heat re-radiation is more pronounced in lanes with heavy traffic, exacerbating localized warming. Densely serviced urban areas with significant traffic volumes thus experience a cumulative effect, with engine heat, emissions, and heat-retaining road surfaces all contributing to elevated local temperatures.

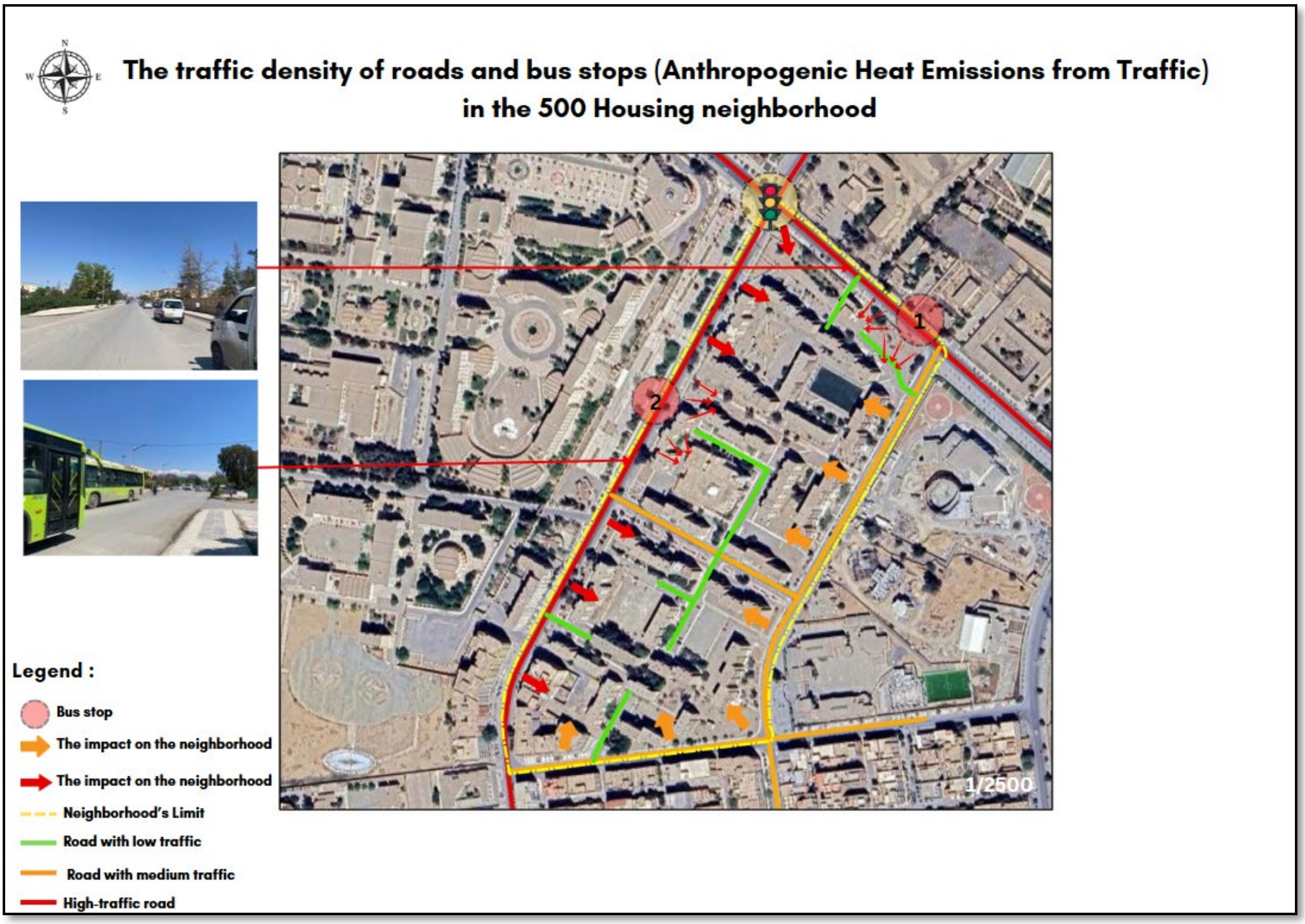


Figure 32: Anthropogenic Heat Emissions from Traffic the neighborhood

(By the Author)

g. Open spaces and Paved Surfaces and Children’s Play areas:

The neighborhood contains a number of unshaded open spaces that lack proper planning and development, both in terms of urban furniture and green infrastructure. These spaces are largely devoid of vegetation and functional design elements, which significantly reduces their environmental and social value. From a microclimatic perspective, such poorly designed open areas contribute directly to the intensification of the (UHI) effect.

They incorporate key contributing factors to UHI formation, including impervious surfaces, absence of tree canopy, limited evapotranspiration, and high solar radiation absorption. Consequently, these unstructured spaces act as localized heat sinks, exacerbating thermal discomfort and undermining the sustainability and livability of the urban environment.

Findings in the 500 Housing Neighborhood indicate that children of various ages and genders engage in play activities in multiple locations that are not designated or appropriately equipped for such purposes. This situation is primarily attributed to the lack of adequate planning and the absence of properly designed and equipped spaces intended for children's recreational use.

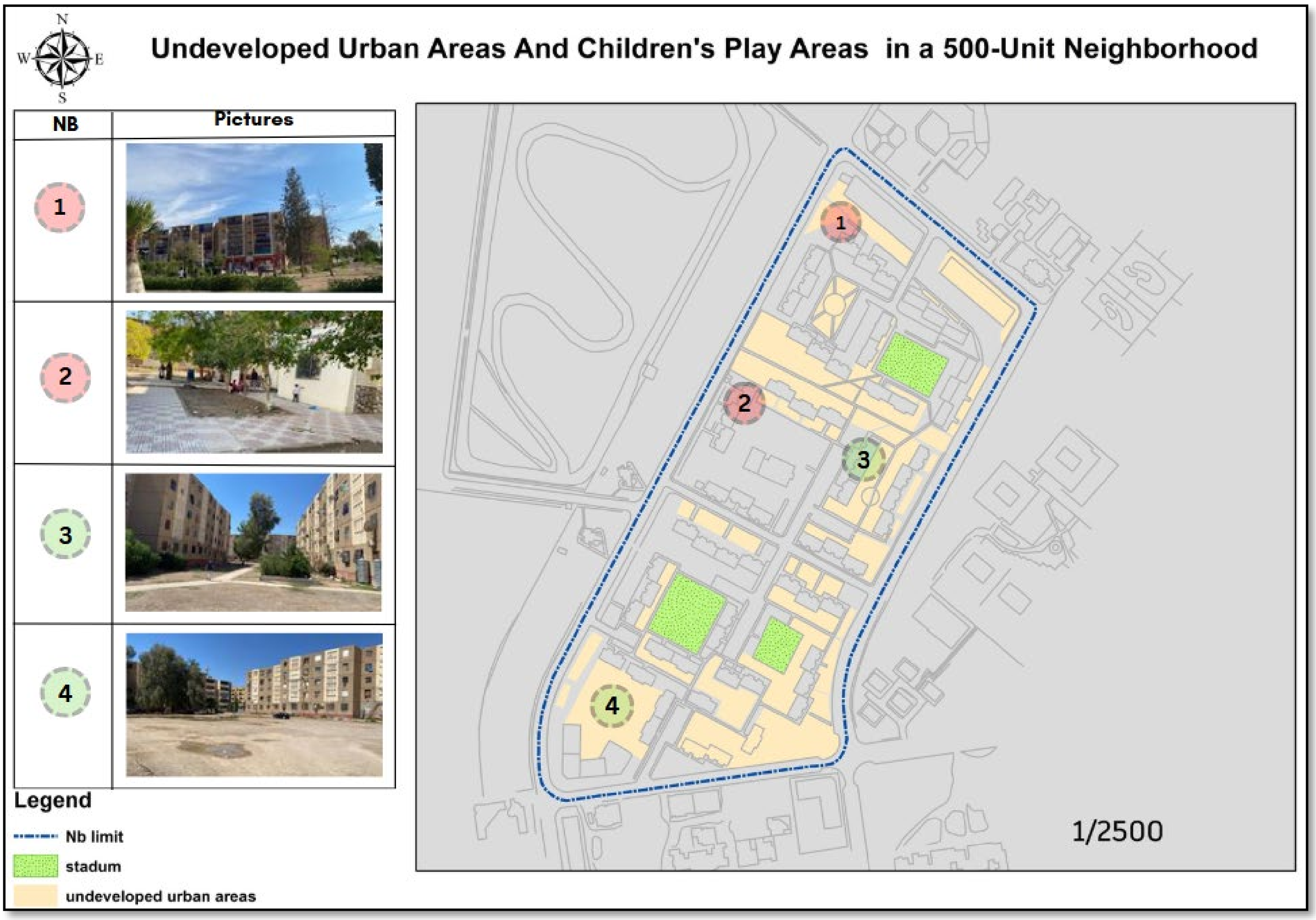


Figure 33: Open spaces in 500-unit neighborhood and Children's Play areas

(By the Author)

VI. General summary:

When examined as a case study**,** the Urban Heat Island (UHI) phenomenon provides valuable insights into the complex interplay between urban development, climate, and public health.

The 500-unit neighborhood highlights how localized urban development patterns can significantly contribute to the Urban Heat Island (UHI) effect. This compact residential area, characterized by high building density, limited green space, and extensive impervious surfaces such as asphalt roads and concrete rooftops, demonstrated a measurable increase in ambient temperatures compared to nearby less-developed areas.

Key findings include :

1. **Surface Material and Layout Influence Temperature Patterns**
   The use of heat-absorbing materials like dark roofs, concrete sidewalks, and paved parking lots in the neighborhood led to elevated surface and near-surface air temperatures, particularly during afternoon and early evening hours. These patterns align with EPA findings on how built surfaces retain and re-emit heat.
2. **Lack of Vegetation Intensifies UHI**
   The neighborhood showed minimal tree canopy coverage and limited landscaped areas. The absence of natural cooling from evapotranspiration contributed to higher local temperatures and reduced thermal comfort for residents. This aligns with broader findings that green infrastructure can mitigate UHI effects effectively.
3. **Health and Comfort Impacts**
   Residents reported increased discomfort during heatwaves and greater reliance on air conditioning, which raised energy demand and utility costs. Vulnerable populations, including the elderly and low-income families, were disproportionately affected, reflecting broader trends observed in UHI-impacted urban areas.
4. **Potential for Mitigation**
   This case study underlines the potential benefits of introducing mitigation strategies such as cool roofing, shade trees, permeable pavements, and community green spaces. Modeling projections suggest that even modest increases in vegetative cover could significantly lower localized temperatures and improve energy efficiency.

VII. Points of Intervention " Solutions and strategies "

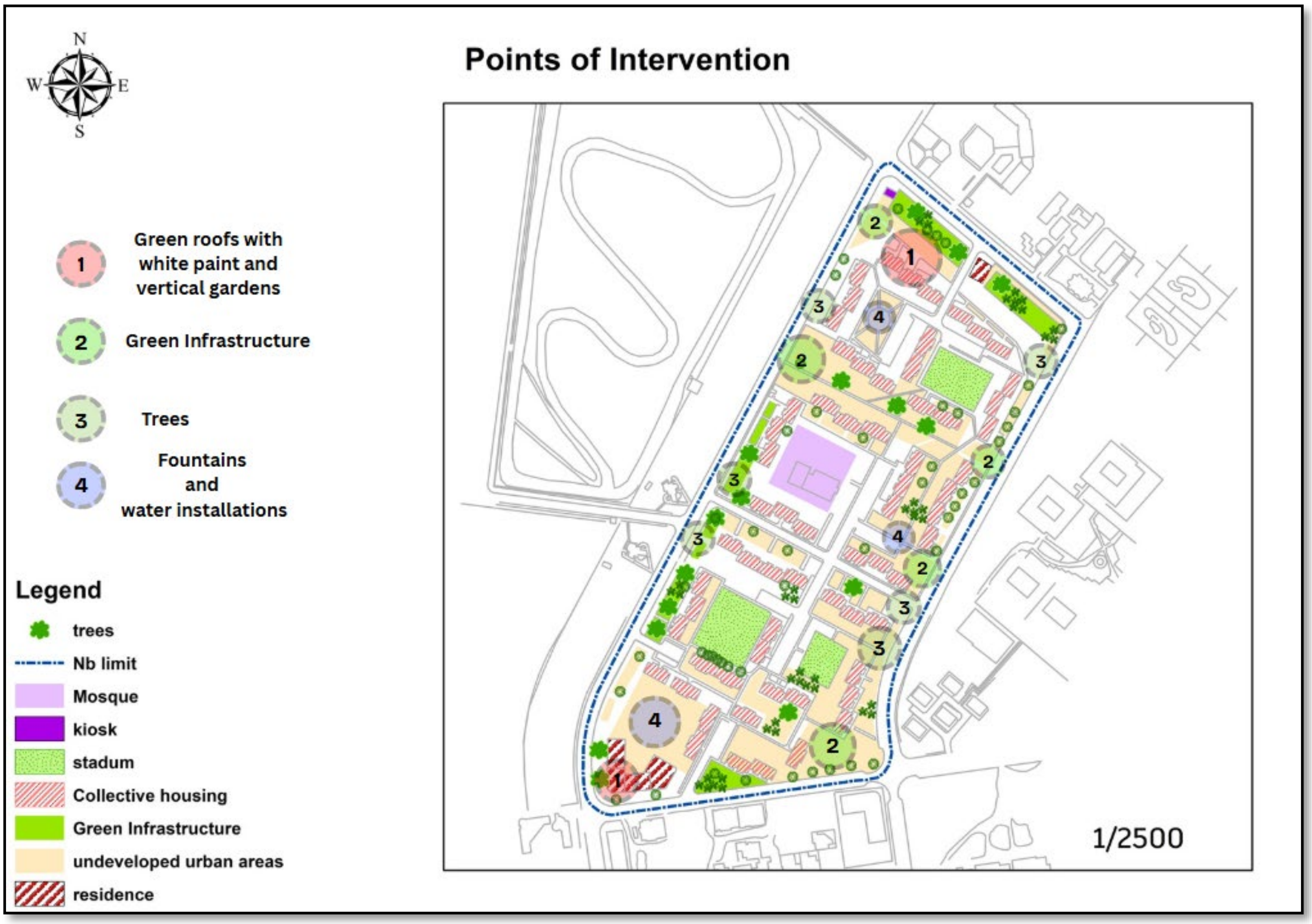


Figure 34: Some points of intervention in the neighborhood **(By the Author)**

As part of our analysis of the urban heat island phenomenon, which negatively impacts thermal comfort and quality of life in the studied neighborhood, we propose a set of environmentally sustainable and easily applicable interventions.

These measures include :

- Painting rooftops white to reduce heat absorption.
- Planting native trees to provide natural shading.
- Increasing green Infrastructures to support ecological balance.
- Installation of fountains and water features to help cool the air through evaporation (enhance urban aesthetics and provide more comfortable).

Complementary solutions such as the use of cool building materials, improved urban design to enhance natural ventilation, and the promotion of urban agriculture can further contribute to reducing temperatures and improving overall living conditions.

Conclusion

This field study aims to evaluate the manifestations and underlying causes of the Urban Heat Island (UHI) phenomenon in the 500 Housing neighborhood, an area characterized by medium to high urban density.

The findings reveal a notable rise in local temperatures, particularly during nighttime hours, when compared to adjacent rural zones and less densely populated districts. This thermal elevation underscores the vulnerability of urban microenvironment (even at relatively small scales) to the effects of anthropogenic heat accumulation.

The UHI effect observed in the 500 Housing area is driven by a convergence of interrelated factors: Neighborhood density and functional diversity play a pivotal role.

As a mixed-use zone combining residential and commercial activities, the neighborhood experiences high human activity, attracting not only residents but also daily visitors and consumers. This leads to increased energy demand and elevated anthropogenic heat emissions.

Vehicular traffic contributes substantially to thermal pollution. Roads with heavy traffic, intersections, traffic signals, and bus stops generate localized heat through engine emissions, friction, and frequent stop-and-go behavior, all of which intensify surface and air temperatures.

The widespread use of air conditioning systems further compounds the issue. With approximately 500 residential air conditioning units) in addition to those in commercial spaces (significant quantities of waste heat are expelled into the outdoor environment, particularly during peak summer periods. The physical composition of the urban landscape, especially asphalt and concrete surfaces, exacerbates heat retention.

These materials absorb solar radiation throughout the day and release it during the night, prolonging the neighborhood’s exposure to elevated temperatures.

The lack of sufficient green spaces is another critical factor, Vegetation plays a key role in mitigating urban heat through shading and evapotranspiration, and its absence reduces the area's natural cooling capacity.

The orientation of buildings affects sun exposure, airflow, and shading, all of which influence how heat accumulates or dissipates across different times of day.

These variables interact in a self-reinforcing feedback loop: rising ambient temperatures increase the demand for mechanical cooling, which in turn intensifies anthropogenic heat emissions, further worsening the UHI effect. Importantly, the 500 Housing neighborhood serves as a microcosm of broader urban heat challenges, demonstrating that even small-to-medium-scale developments are not exempt from UHI dynamics.

The study highlights the urgent need for sustainable urban interventions.

VIII. Solutions and strategies

In order to minimize the impacts of urban heat islands it is necessary to commit to sustainable urban development here they are some strategies that can be used to mitigate urban heat islands effect:

- **Restoring natural elements to cities by increasing green Infrastructure coverage:**

Vegetation and plant life play a vital role in mitigating urban heat, making them among the most effective strategies for creating urban cool islands

Urban greening brings multiple benefits:

- **Trees:** By providing shade and promoting evapotranspiration, trees help lower surrounding air temperatures.
- **Green roofs and vertical gardens:** These green structures reduce heat absorption and enhance a building's thermal insulation, thereby decreasing reliance on air conditioning systems.
- **Urban parks and gardens:** Public green areas not only help cool urban environments but also contribute to improved living conditions and overall well-being.

However, green solutions alone are not enough, and must be backed up by other strategies.

- **Water-based, strategies offer effective means of cooling urban environments:**

- **Fountains and water installations:** These features absorb heat and aid in dissipating it, thereby lowering the surrounding air temperature.
- **Urban misting and evaporative systems:** These cooling technologies can be deployed in public areas to decrease ambient heat levels effectively.

In addition to mitigating heat, such water-centric solutions enhance urban aesthetics and provide more comfortable, inviting spaces for city residents contributing positively to their overall quality of life.

- **Painting roofs white :**

Darker colors absorb more heat, so increasing the reflectivity of buildings can reduce heat.
The easiest way to retrofit that logic is to paint rooftops white.

- **Changing citizens' behavior and urban management:**

Effectively mitigating the impacts of UHI necessitates not only technical or infrastructural interventions but also the adoption of behavioral modifications and supportive public policy, collectively referred to as "soft" solutions.
These strategies aim to engage city dwellers in practices that reduce anthropogenic heat production and improve urban resilience.

- **Energy Demand Reduction:** Lowering energy consumption is directly correlated with reduced anthropogenic heat emissions.
  Promoting the development and widespread adoption of energy-efficient buildings and infrastructure is therefore fundamental to UHI mitigation.
- **Transitioning from Combustion-Based Mobility:** Reducing reliance on private motor vehicles powered by internal combustion engines is critical. This includes promoting "soft mobility" alternatives such as walking and cycling, pedestrianizing key urban zones, implementing traffic-calming measures, and incentivizing the transition to electric vehicles.
  Each contributing to the decline in heat emissions associated with vehicular transport.
- **Public Awareness and Behavioral Adaptation:** Enhancing public understanding of UHI through targeted education and communication

campaigns are essential.

Simple behavioral measures, such as prioritizing public transport and active mobility, limiting air conditioning use, ventilating buildings during cooler nighttime hours, and managing solar exposure through shading, can collectively help moderate urban temperatures and improve population preparedness during extreme heat events.

Though individually modest, these behavioral and policy-driven actions can have a cumulative and meaningful impact on reducing urban heat, fostering both climatic and social resilience in cities.

➢ Integrating Heat-Responsive Design in Urban Planning

Proactive urban and architectural design plays a pivotal role in mitigating urban heat. Adopting a diversified skyline (through the strategic variation of building heights) can significantly enhance natural ventilation, facilitating the dispersion of accumulated heat and improving thermal comfort at the street level.

Incorporating passive cooling strategies into the design of new buildings, such as optimizing orientation, maximizing cross-ventilation, and using thermal mass, can substantially reduce reliance on mechanical air conditioning systems.

Additionally, integrating shading elements (including overhangs and canopies) at the early stages of urban development ensures long-term resilience and comfort, rather than relying on post-construction retrofitting. To enable such thermally adaptive design, cities may need to revise existing planning frameworks and building codes to incentivize climate-sensitive construction practices. Looking ahead, one of the most impactful and cost-effective approaches for urban areas is to institutionalize best practices in heat-conscious planning, thereby preventing further exacerbation of urban heat challenges and minimizing the need for corrective interventions in the future.

REFERENCES

Roth, M. (2013). Fernando, H.J.S. Dans *Urban Heat Islands. In Handbook of Environmental Fluid Dynamics* (pp. 143–159). USA: Taylor & Francis Group, LLC.

Abdel-Ghany, A., Al-Helal, I., & Shady, M. (2013). Human Thermal Comfort and Heat Stress in an Outdoor Urban Arid Environment A Case Study. *Adv. Meteorol*.

Abulibdeh, A. (2021). Analysis of urban heat island characteristics and mitigation strategies for eight arid and semi-arid gulf region cities. *Environmental Earth Sciences(Springer)*, 1-26.

Akbari, H., & Rose, L. (2001). Characterising the Fabric of the Urban Environment: A Case Study of Metropolitan Chicago. *Illinois; Lawrence Berkeley National Laboratory*.

Akbari, H., Bretz, S., Kurn , D., & Hanford, J. (1997). Peak power and cooling energy savings of high-albedo roofs. *Energy Build*, 117-126.

Akbari, H., Rose, L., & Taha, H. (2003). Analyzing the land cover of an urban environment using high-resolution orthophotos. *Landsc Urban Plan*, 1-14.

Ansar, k., Soumendu , C., Walter , L., Rupali , K., Apurba , D., & Aprajita, M. (s.d.). City-scale Modeling of Urban Heat Islands for Kolkata. *Climate Change,Hazards and Adaptation Options*, 89-135.

Arnfield , A. (2003). Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. *Int J Climatol*, 1-26.

Bretz SE, & Akbari , H. (1997). Long-term performance of high-albedo roof coatings. *Energy Build*, 159-167.

Bruna , G., Júlia Calvaitis , P., Paula, R., Fabiane , B., & Natalia, H. (s.d.). Influence of Vegetation in the Creation of Urban Microclimates. *Climate Change Hazards and Adaptation Options*, 161-175.

Chow, W., Brennan, D., & Brazel, A. (2012). Urban heat island research in Phoenix. *Arizona*, 517–530.

Deilami, K., Kamruzzaman, M., & Liu, Y. (2018). Urban heat island effect: A systematic review of spatio-temporal factors, data, methods,and mitigation measures. *Int. J. Appl. Earth Obs. Geoinf.*, 30-42.

F, F. (2009). Detection of urban warming in recent temperature trends in Japan. *Int J Climatol*, 1811–1822.

Fadhil, M., Hamoodi, M. N., & Ziboon, A. R. (2025). Mitigating urban heat island effects in urban environments :strategies and tools. *IOP Publishing*, 1-11.

G, N., HA, B., & A, L. (2020). Exploring temperature indices by deriving relationship between land surface temperature and urban landscape. *Remote Sens Appl Soc Environ*, 100-299.

Gartland, L. (2008). Heat Islands: Understanding and Mitigating Heat in Urban Areas. *Earthscan Publications*, 57-83.

Georgakis, C., & Santamouris, M. (2017). Determination of the Surface and Canopy Urban Heat Island in Athens Central Zone Using Advanced Monitoring. *Climate*.

George , L., & Michael , M. (2008). Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine*, 429-430.

Georgiadis, T. (2017). Oxford Handbooks Online. Dans T. Georgiadis, *Urban Climate and Risk* (pp. 1–29). Oxford, UK: Oxford University Press.

Grimmond, S. (2007). Urbanization and global environmental change:local effects of urban warming. *Geogr*, 83-88.

Ibrahim, S., Ibrahim, N., Wahid, J., Goh, N., Koesmeri, D., & Koesmeri, M. (2018). The Impact of Road Pavement on Urban Heat Island (UHI) Phenomenon. *International Journal of Technology*, 1597-1608.

J. S, S., , R. M, d., & C. A. G, S. (2018). Spatiotemporal Impact of Land Use/Land Cover Changes on Urban Heat Islands: A Case Study of Paço do Lumiar, Brazil. *Building and Environment*, 279–292.

Kangning , H., Xia , L., Xiaoping, L., & Karen , C. (2019). Projecting global urban land expansion and heat island intensification through 2050. *Environ.Res. Lett*, 1-13.

Kubota, T., Lee, H., Trihamdani, A., Phuong, T., Tanaka, T., & Matsuo, K. (2017). Impacts of land use changes from the Hanoi Master Plan 2030 on urban heat islands. *Cooling effects of proposed green strategies*, 295–317.

Lili , T., Zhihao , Q., Wenjuan, L., Jun Geng, Lechan , Y., Shuhe , Z., . . . Fei, W. (2016). Surface urban heat island effect and its relationship with urban expansion in Nanjing, China. *J. Appl. Remote Sens*.

Lili Tu, Zhihao Qin , Wenjuan Li , Jun Geng , Lechan Yang , Shuhe Zhao , . . . Fei Wang. (2016). Surface urban heat island effect and its relationship with urban expansion in Nanjing, China. *applied remote sensing*, 1-2.

Mirzaei, P. (2015). Recent challenges in modeling of urban heat island. *Sustain Cities Soc*, 200-206.

Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *J. Environ. Manag*, 522-538.

Muhammad , R., Wan, M., Sahibin, A., Hazem , G., Hussein , A., Ahmed , A., & Motrih, A.-M. (2023). Relationships between land use types and urban heat island intensity in Hulu Langat district, Selangor, Malaysia. *Rendana et al. Ecological Processes*, 1-14.

Oke, T. (1987). Dans T. Oke, *Boundary Layer Climates* (p. 435). Cambridge, UK: Routledge, Taylor and Francis Group.

Ongsomwang, S., Dasananda, S., & Prasomsup, W. (2018). Spatio-temporal urban heat island phenomena assessment using LANDSAT imagery. *Environ Nat Resour J*, 299–344.

Rehan, R. (2016). Cool city as a sustainable example of heat island management case study of the coolest city in the world. *HBRC J.*, 191-204.

Rizwan , A., Dennis, L., & Chunho, L. (2008). A review on the generation, determination and mitigation of Urban Heat Island. *J Environ Sci*, 120-128.

Roth, M. (2013). Urban heat islands. *Fernando HJS (ed) Handbook of environmental fluid dynamics*, 143–159.

Sidler, O. (2003). L’inertie Thermique Des Batiments. *Consommation Et Confort D’ete En Climat Mediterraneen*.

Stempihar, J., Pourshams-Manzouri, T., Kaloush, K., & Rodezno, M. (2012). Porous Asphalt Pavement Temperature Effects for Urban Heat Island Analysis. *Transp. Res. Rec*, 123-130.

Stone, B. (2007). Urban and rural temperature trends in proximity to large US cities. *Int J Climatol*, 1801–1807.

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

Voogt, J., & Oke, T. (2003). Thermal remote sensing of urban climates. *Remote Sens Environ*, 370–384.

Walter , L., Leyre , E., Victoria , O., & Abul , Q.-A. (2017). An Evidence-Based Review of Impacts, Strategies and Tools to Mitigate Urban Heat Islands. *International Journal of Environmental Research and Public Health*, 1-29.

Walter Leal Filho, Gustavo J. Nagy · Marco Borga ·, Pastor David Chávez Muñoz ·, & Artur Magnuszewski Editors. (2010). *Climate Change,Hazards and Adaptation Options.*

Wan, Z. (2008). New refinements and validation of the MODIS land-surface temperature/emissivity products. *Remote Sens Environ*, 59–74.

Wijeyesekera, D., Nazari, N., Lim, S., Masirin, M., Zainorabidin, A., & Walsh, J. (2012). Investigation into the Urban Heat Island Effects from Asphalt Pavements. *OIDA Int. J. Sustain. Dev*, 97–118.

الجمهورية الجزائرية الديمقراطية الشعبية
REPUBLIQUE ALGERIENNE DEMOCRATIQUE ET POPULAIRE
وزارة التعليم العالي والبحث العلمي
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE
جامعة محمد بوضياف – المسيلة
Université Mohamed Boudiaf - M'SILA
معهد تسيير التقنيات الحضرية
Institut de Gestion des Techniques Urbaines

ملحق بالقرار رقم 1082 المؤرخ في 27 ديسمبر 2020
الذي يحدد القواعد المتعلقة بالوقاية من السرقة العلمية و مكافحتها

الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي و البحث العلمي

مؤسسة التعليم العالي والبحث العلمي : جامعة محمد بوضياف –المسيلة

تصريح شرفي

خاص بالالتزام بقواعد النزاهة العلمية لانجاز بحث

أنا الممضي أسفله:

السيد [ة]: **أوذينة شروق نور العين** الصفة (أستاذ،باحث،طالب) : **طالب**

الحامل (ة) لبطاقة التعريف الوطنية رقم : **210801896** والصادرة بتاريخ : **2024/08/21**

المسجل [ة] بكلية /معهد : **معهد تسيير التقنيات الحضرية** قسم : **تسيير المدينة**

و المكلف[ة] بانجاز أعمال بحث[~~مذكرة التخرج~~، مذكرة ماستر ،~~مذكرة ماجستير~~، ~~أطروحة دكتوراه~~]

عنوانها : **Urban Heat Island risk assessment and Hazard mitigation study M'sila city**

أصرح بشرفي أني ألتزم بمراعاة المعايير العلمية و المنهجية و معايير الأخلاقيات المهنية و التزامه الأكاديمية المطلوبة في انجاز البحث المذكور أعلاه.

التاريخ : **2025/06/10**

توقيع المعني [ة]