

URBAN HEAT ISLAND MITIGATION THROUGH URBAN
FARMING USING REMOTE SENSING
IN MAIDUGURI NIGERIA

LADAN TIJJANI ABUBAKAR

THESIS PRESENTED TO QUALIFY FOR A DOCTOR OF PHILOSOPHY

FACULTY OF HUMAN SCIENCES
SULTAN IDRIS EDUCATION UNIVERSTY

2025

UPSI/PS-3/BO 32
Print : 00 ms: 1/1



Please tick (✓)
Project Paper
Masters by Research
Master by Mixed Mode
PhD

INSTITUTE OF GRADUATE STUDIES

DECLARATION OF ORIGINAL WORK

This declaration is made on the 9th day of September 2025

i. Student's Declaration:

I, **LADAN TIJJANI ABUBAKAR** with the Matric No. P20192001208 Faculty of Human Sciences
I hereby declare that the work entitled **Urban Heat Island Mitigation through Urban Farming Using Remote Sensing in Maiduguri, Nigeria**

is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

Signature of the student

ii. Supervisor's Declaration:

I **PROF. MADYA DR. MOHD HAIRY BIN IBRAHIM** hereby certifies that the work entitled **URBAN HEAT ISLAND MITIGATION THROUGH URBAN FARMING USING REMOTE SENSING IN MAIDUGURI NIGERIA** was prepared by the above-named student, and was submitted to the Institute of Graduate Studies as a * partial/full fulfillment for the conferment of **DOCTOR OF PHILOSOPHY (PhD)**, and the aforementioned work, to the best of my knowledge, is the said student's work.

19/9/2025

Date

Signature of the Supervisor



**INSTITUT PENGAJIAN SISWAZAH /
INSTITUTE OF GRADUATE STUDIES**

**BORANG PENGESAHAN PENYERAHAN TESIS/DISERTASI/LAPORAN KERTAS PROJEK
DECLARATION OF THESIS/DISSERTATION/PROJECT PAPER FORM**

Tajuk / Title: **URBAN HAET ISLAND MITIGATION THROUGH URBAN
FARMING USING REMOTE SENSING IN MAIDUGURI NIGERIA**

No. Matrik / Matric's No.: **P20192001208** _____

Saya / I: **LADAN TIJJANI ABUBAKAR** _____

(Nama pelajar / Student's Name)

mengaku membenarkan Tesis/Disertasi/Laporan Kertas Projek (Kedoktoran/Sarjana)* ini disimpan di Universiti Pendidikan Sultan Idris (Perpustakaan Tuanku Bainun) dengan syarat-syarat kegunaan seperti berikut:-

acknowledged that Universiti Pendidikan Sultan Idris (Tuanku Bainun Library) reserves the right as follows:-

1. Tesis/Disertasi/Laporan Kertas Projek ini adalah hak milik UPSI.
The thesis is the property of Universiti Pendidikan Sultan Idris
2. Perpustakaan Tuanku Bainun dibenarkan membuat salinan untuk tujuan rujukan dan penyelidikan.
Tuanku Bainun Library has the right to make copies for the purpose of reference and research.
3. Perpustakaan dibenarkan membuat salinan Tesis/Disertasi ini sebagai bahan pertukaran antara Institusi Pengajian Tinggi.
The Library has the right to make copies of the thesis for academic exchange.
4. Sila tandakan (✓) bagi pilihan kategori di bawah / Please tick (✓) for category below:-

SULIT/CONFIDENTIAL

Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub dalam Akta Rahsia Rasmi 1972. / Contains confidential information under the Official Secret Act 1972

TERHAD/RESTRICTED

Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan ini dijalankan. / Contains restricted information as specified by the organization where research was done.

TIDAK TERHAD / OPEN ACCESS

(Tandatangan Pelajar/ Signature)

(Tandatangan Penyelia / Signature of Supervisor
& (Nama & Cap Rasmi / Name & Official Stamp)

Tarikh: 9th September 2025

Catatan: Jika Tesis/Disertasi ini SULIT @ TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu dikelaskan sebagai SULIT dan TERHAD.

Notes: If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

ACKNOWLEDGEMENT

Alhamdulillah, all thanks and praises are due to Allah (SWT) for granting me life, strength, and good health throughout this journey, and for making the successful completion of this PhD a reality.

I extend my deepest appreciation to my supervisor, Assoc. Prof. Dr. Mohd Hairry bin Ibrahim, and my co-supervisor, Dr. Kamarul Ismail, for their invaluable guidance, patience, and continuous support. My sincere gratitude also goes to the Dean, Assoc. Prof. Nor Kalsum Mohd Isa, and to all academic and non-academic staff of the Department of Geography and the Faculty of Human Science (FSK) for their encouragement and support throughout the course of this study.

My appreciation also goes to all my examiners for their objective criticism and crucial feedback that refined and strengthened the quality of this work. I am also grateful to all staff at UPSI for their dedication, guidance, and motivation. Special thanks to the UPSI Postgraduate Institute, the International Mobility Center, and the UKLK for their various forms of assistance during my academic journey.

I wish to express my heartfelt appreciation to the TETFund Nigeria for providing the financial support through its scholarship programme, which made this academic pursuit possible.

To all my friends and colleagues within the UPSI community, thank you for your critical feedback, encouragement, and camaraderie. Your support has been instrumental to my success.

A special note of gratitude goes to my beloved family. To my parents, Yagana Shiwa and Abubakar Ladan, your prayers and love have sustained me. I also appreciate Engr. Tijani M. Bukar and his late wife Fatime Kyari Dikwa, whose support was deeply impactful. My heartfelt thanks to my dear wife, Zainab Abba Masta, and our children, Abbamasta and Fatima, for their patience, love, and unwavering support throughout this journey.

To my dear friends and brothers Mohammed Kyari Dikwa, Umar Bukar Alhaji, Alhaji Aisami, Babagana Lawan, Abba Ali Ladan, Engr. Kamselum Bukar, Abubakar Imam, Babagana Shehu, Zanna Ballak, Dr. Ihsan and Dr. Dogo, thank you for your unconditional support, prayers, and relentless contributions. I cannot thank you enough. May Allah reward you all abundantly.

ABSTRACT

Urban heat islands (UHI) present critical challenges to urban environments, intensifying heat-related health risks and reducing livability. This study evaluates the potential of urban farming to mitigate UHI effects in Maiduguri, Nigeria, by analyzing changes in land surface temperature (LST), land use/land cover (LULC), and vegetation cover over a 30-year period (1992–2022). Landsat satellite imagery processed through ArcGIS and Google Earth Engine was validated using ground truth observations collected with a Garmin eTrex 10 GPS device and supplemented by long-term climatic data from the Nigerian Meteorological Agency (NiMET). ENVI-met microclimate simulations quantified the impact of urban farming on surface temperature and humidity. Results show significant urban expansion accompanied by decreased vegetation, driving higher LST values and intensifying UHI impacts. By 2022, LST peaked at 32.98°C, with UHI intensity rising steadily throughout the study period. ENVI-met simulations indicate that increasing urban farming coverage leads to notable cooling effects and improved vegetation health, with a 0.5°C temperature reduction and a 2.0% humidity increase observed at 10% urban farming coverage. A survey of 400 residents revealed limited awareness of UHI but strong recognition of urban farming's benefits for food security and environmental sustainability. These findings underscore urban farming as an effective, nature-based strategy for UHI mitigation and advocate for its integration into urban planning to foster resilient, sustainable cities in rapidly urbanizing and arid regions such as Maiduguri.

MITIGASI PULAU HABA BANDAR MELALUI PERTANIAN BANDAR MENGUNAKAN PENDERIAN JAUH DI MADIDUGURI NIGERIA

ABSTRAK

Pulau haba bandar (UHI) memberikan cabaran kritikal kepada persekitaran bandar, meningkatkan risiko kesihatan berkaitan haba dan mengurangkan kebolehtinggalan. Kajian ini menilai potensi pertanian bandar untuk mengurangkan kesan UHI di Maiduguri, Nigeria, dengan menganalisis perubahan dalam suhu permukaan tanah (LST), guna tanah/litupan tanah (LULC), dan litupan tumbuh-tumbuhan dalam tempoh 30 tahun (1992–2022). Imej satelit Landsat yang diproses melalui ArcGIS dan Enjin Google Earth telah disahkan menggunakan pemerhatian kebenaran tanah yang dikumpul dengan peranti GPS Garmin eTrex 10 dan ditambah dengan data iklim jangka panjang daripada Agensi Meteorologi Nigeria (NiMET). Simulasi iklim mikro yang dipenuhi ENVI mengukur kesan pertanian bandar terhadap suhu dan kelembapan permukaan. Keputusan menunjukkan pengembangan bandar yang ketara disertai dengan penurunan tumbuh-tumbuhan, memacu nilai LST yang lebih tinggi dan meningkatkan kesan UHI. Menjelang 2022, LST memuncak pada 32.98°C, dengan keamatan UHI meningkat secara berterusan sepanjang tempoh kajian. Simulasi ENVI-met menunjukkan bahawa peningkatan liputan pertanian bandar membawa kepada kesan penyejukan yang ketara dan kesihatan tumbuh-tumbuhan yang bertambah baik, dengan pengurangan suhu 0.5°C dan peningkatan kelembapan 2.0% diperhatikan pada liputan pertanian bandar sebanyak 10%. Tinjauan ke atas 400 penduduk mendedahkan kesedaran terhad tentang UHI tetapi pengiktirafan yang kukuh terhadap faedah pertanian bandar untuk keselamatan makanan dan kelestarian alam sekitar. Penemuan ini menekankan pertanian bandar sebagai strategi berasaskan alam semula jadi yang berkesan untuk mitigasi UHI dan menyokong penyepaduannya ke dalam perancangan bandar untuk memupuk bandar yang berdaya tahan, mampan di kawasan perbandaran yang pesat dan gersang seperti Maiduguri.

CONTENTS

	Page
DECLARATION OF ORIGINAL WORK	ii
DECLARATION OF THESIS	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
ABSTRAK	vi
CONTENTS	vii
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xvii
LIST OF APPENDICES	xx
CHAPTER 1 INTRODUCTION	
1.1 Overview	1
1.2 Background of The Study	5
1.3 Rational of the Research	13
1.4 Statement of problem	20
1.5 Aim of the study	27
1.6 Objectives of the study	28
1.7 Research Questions	28

1.8 Scope of the study	29
1.9 Operational Definition	29
1.10 Significance of the Study	32
1.11 Summary	33

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction	35
2.2 The Concept of Urban Heat Island	36
2.3 Types of Urban Heat Islands	42
2.4 Urban Heat Island and Human Health	43
2.5 Urban Heat Island Intensity	45
2.6 Urban Heat Island and Climate Change	47
2.7 Relationship between Urban Heat Island and Land Use/Land Cover	56
2.8 Urban Heat Island Studies in Nigeria	57
2.9 Issues Within UHI Communication	59
2.10 Urban heat island mitigation strategies, the blue, green and grey	61
2.10.1 Green Infrastructure	63
2.10.2 Urban Parks	63
2.10.3 Green and Cool Roof	65
2.10.4 Vertical Farming/Sky Farming	66
2.10.5 Trees	68
2.10.6 Urban Farming, Urban/Community Garden	70
2.10.7 Blue Infrastructure	72
2.10.8 Grey Infrastructure	77

2.11 Remote Sensing and UHI	81
2.12 Landsat Sensors	84
2.13 The Origin of Urban farming/Urban agriculture	89
2.14 The Concept of Urban Farming	94
2.15 Types of Urban Farming	101
2.16 Significance of Urban Farming	105
2.17 The Imperative of Urban Farming in Maiduguri	114
2.18 Summary	121

CHAPTER 3 METHODOLOGY

3.1 Introduction	123
3.2 Historical Background of the Study Area	124
3.2.1 Study Area Location	128
3.2.2 Growth and Development of Borno State	132
3.2.3 Size and population	134
3.2.4 Weather and Climate	135
3.2.5 Soil	147
3.2.6 Landform Topography	148
3.2.7 Geology	153
3.2.8 Hydrogeology	154
3.2.9 Drainage System	157
3.2.10 Vegetation	160
3.2.11 Transport System	160
3.2.12 Land use	162

3.3 Research Design	166
3.4.1 Sources of Data	166
3.3.2 Data Assembly and Management	167
3.4.3 Image Pre-processing	168
3.4.4 Image Classification	170
3.4.5 Accuracy Assessment	171
3.4.6 Derivation of LST from Landsat and retrieval of brightness	171
3.4.6.1 Conversion of DN to TOA Spectral Radiance	174
3.4.6.2 Conversion to Brightness Temperature (BT)	174
3.4.6.3 Surface Emissivity and Final LST Estimation	175
3.4.7 Normalized Difference Vegetation Index (NDVI)	177
3.5 ENVI-met Simulation	180
3.5.1 ENVI-met Simulation Procedure	182
3.6. Population and Sampling	184
3.6.1 Sample	184
3.6.2 Sample Frame	185
3.6.3 Sample wards and sample size	190
3.6.4 Pilot study	191
3.6.5 Exploratory Factor Analysis	192
3.6.6 Data Source from	194
3.7 Data Analysis	197
3.7.1 Materials and Method for the Analysis of Objectives	197
3.8 Summary	200

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction	203
4.2 Data acquisition	108
4.3 Image Processing LULC Classification	211
4.4 LULC accuracy assessment	213
4.5 Changes in Magnitude, Trend Percentage, and Annual Change Rate	217
4.6 Land Surface Temperature (LST) Dynamics	223
4.7 Derivation of NDVI, from the Landsat Imagery	226
4.8 Urban Heat Islands Estimation	228
4.9 Spatiotemporal Pattern of LU/LC Dynamics	236
4.10 Relationship Between LST and Vegetation Cover	248
4.11 Urban Farming Practices in Maiduguri	250
4.11.1 Farm Site 1: Gamboru, Old Maiduguri, Gongulong	255
4.11.2 Farm Site 2: Bale Galtimari, Mairi	255
4.11.3 Farm Site 3: Maisandari	256
4.11.4 Farm Site 4: Mairi	256
4.12. ENVI-met Simulation Report	258
4.12.1 Simulation Results	261
4.12.2 Validation of ENVI-met Model Using NiMET and Ground	267
4.13 Urban Dwellers' Perspectives on Understanding and Perception	268
4.13.1 Urban Dwellers' Perception on UHI Phenomenon	268

4.13.2 Socio-demographic Characteristics of Respondents	269
4.13.3 Demographic characteristics of urban dwellers	273
4.13.4 Awareness and Understanding of UHI Phenomenon	279
4.13.5 Challenges and Barriers of UF for UHI Mitigation	306
4.14 Summary	325
CHAPTER 5 DISCUSSION, SUMMARY AND CONCLUSION	
5.1 Introduction	327
5.2 Researcher's Discussion and Further Argument	329
5.2.1 Assessing the Level of UF Practice and the UHI	329
5.2.2 Analyzing Spatiotemporal Trends in LULC, LST, NDVI	332
5.2.3 Assessing Urban Residents' Knowledge and Perceptions	335
5.2.4 Evaluating the Effectiveness of UF in Reducing UHI	337
5.3 Summary	340
5.4 Implications and Recommendations	342
5.5 Conclusion	345
REFERENCES	347
APPENDICES	379

LIST OF TABLES

Table No.		Page
2.1	Summary of band designations and pixel size (m) for all Landsat satellites (LS) and sensors	87
2.2	Stages of the historical development of urban farming	93
2.3	Studies implementing urban farming as a strategy for Urban Heat Island mitigation	99
3.1	Spatial and Temporal Distribution of Average Temperatures in Maiduguri (1992–2022)	138
3.2	Distribution of Average Relative Humidity (%) in Maiduguri	142
3.3	Annual Rainfall (mm) in Maiduguri Wards (1992–2022)	146
3.4	Spectral Bands Used in the Study	176
3.5	Sample wards and sample size	190
3.6	Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity	192
4.1	Details of Landsat datasets of the study area, Maiduguri.	207
4.2	Area (km ²) and percentage of Land Cover classes during the study period 1992 – 2022	209
4.3	The description and composition of the LULC types used in the study.	213
4.4	Land use land cover accuracy assessment.	216
4.5	Change Magnitude of Maiduguri Metropolis from 1992 – 2022.	219
4.6	The Trends of the LULC from 1992-2022	221

4.7	The annual change rate of the LULC from 1992-2022	222
4.8	Summary of LST (°C) for Maiduguri Metropolis (1992–2022)	226
4.9	Urban Farming Sites: Size and Perimeter (2002-2022)	254
4.10	Total Area and Perimeter of Urban Farming Sites (2002-2022)	255
4.11	Baseline data used for the simulation	259
4.12	Scenario 1: 10% Urban Farming Coverage	260
4.13	Scenario 2: 20% Urban Farming Coverage	260
4.14	Scenario 3: 30% Urban Farming Coverage	260
4.15	Simulated result of different urban farming Scenario and how it reduces temperature and Humidity	261
4.16	Demographic Characteristics of Urban Dwellers	270
4.17	Environmental Impact and Lifestyle Choices of urban dwellers	276
4.18	Responses on Awareness and Understanding of Urban Heat Island Phenomenon	284
4.19	Perception and Attitude Towards UHI Mitigation and UF	266
4.20	Challenges and Barriers of Urban Farming for UHI Mitigation	306
4.21	Initiative and Adaptation Measures for UHI Mitigation	317

LIST OF FIGURES

No. Figures		Page
1.1	Figure 1.1 Research gap.	24
2.1	The formation of UHI and temperature profile.	38
2.2	Landsat mission series and management history.	86
2.3	Conceptual Framework for UHI Mitigation Using Urban Farming Potential.	120
3.1	Map of Borno State showing Maiduguri and its environs.	138
3.2	Annual Average Temperature Maps of Maiduguri	139
3.3	Annual Average Relative Humidity of Maiduguri (1992– 2022).	141
3.4	Annual Average Rainfall Map of Maiduguri (1992–2022).	144
3.5	Relief of Maiduguri Metropolitan Area.	150
3.6	Cross section of the multi-layered aquifer system	156
3.7	Drainage system in Maiduguri Metropolitan.	159
3.8	Types of Data Collected.	194
4.1	UHI Pattern of Maiduguri in 2002 with Raster-Based Tempt	232
4.2	UHI Pattern of Maiduguri in 2012 with Raster-Based Tempt	233
4.3	UHI Pattern of Maiduguri in 2022 with Raster-Based Tempt	235

4.4	LULC distribution of Maiduguri Metropolis from 1992 to 2022	240
4.5	Classified LULC Maps; 1992, 2002, 2012, and 2022	243
4.6	LST Distribution of Maiduguri Metropolis in 1992, 2002, 2012, and 2022	245
4.7	NDVI Spatial Distribution of NDVI of Maiduguri Metropolis in 1992 – 2022.	247
4.8	Farm site Spatial Distribution of Maiduguri in 2002 -2022	252
4.9	Humidity ENVI-MET Simulation Results: Temperature Reduction and Increase	262
4.10	Graphic Presentation of Demographic Characteristics of urban dwellers	271
4.11	Graphic Presentation of Demographic Characteristics of urban Dwellers	272

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ANN	Artificial Neural Network
ArcGIS	Arc Geographic Information System Software by ESRI
BGI	Blue-Green Infrastructure
DN	Digital Number
EO	Earth Observation
ETM+	Enhanced Thematic Mapper Plus
ENVI-met	Environmental Meteorology
FAO	Food and Agriculture Organization
FCC	False Colour Composite
GIS	Geographic Information System
GPS	Global Positioning System
GRI	Green Resilient Infrastructure
IDP	Internally Displaced Person
IFAD	International Fund for Agricultural Development
ITOS	Information Technology Outsourcing Services

LST	Land Surface Temperature
LULC	Land Use Land Cover
MLSICM	Maximum Likelihood Supervised Image Classification Method
MLC	Maximum Likelihood Classification
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NESS	National Environmental Satellite System
NGO	Non-Governmental Organization
NIR	Near-Infrared
NOAA	National Oceanic and Atmospheric Administration
OLI	Operational Land Imager
OXFAM	Oxford Committee for Famine Relief
PCI	Park Cool Island
PV	Proportion of Vegetation
RED	Red Band (of the electromagnetic spectrum)
RF	Random Forest
RS	Remote Sensing
SAM	Spectral Angle Mapper
SGDs	Sustainable Development Goals
SPSS	Statistical Package for the Social Sciences
SUHI	Surface Urban Heat Island
SVM	Support Vector Machine

SWIR	Shortwave Infrared
TIR	Thermal Infrared
TM	Thematic Mapper
TOA	Top of Atmosphere
UA	Urban Agriculture
UF	Urban Farming
UHI	Urban Heat Island
UN	United Nations
UPA	Urban and Peri-urban Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WFP	World Food Programme
WGS84	WGS84 - World Geodetic System 1984

LIST OF APPENDICES

- A Respondents Questionnaire
- B Respondent's Information Sheet and Informed Consent
- C1 Ethical Compliance
- C2 Ethical Compliance
- D Reliability
- E1 Validation of ENVI-met Model Outputs Using NiMET
- E2 Accuracy Assessment of Landsat-Derived LULC Maps
- E3 Surface Temperature and Land Use/Land Cover Using Ground Truth Data
- F Publications

CHAPTER 1

INTRODUCTION

1.1 Overview

Today, there are over four billion urban residents worldwide, with over 863 million living in informal settlements, and this number is growing by approximately one million every ten days (Acuto et al., 2018; Elmqvist et al., 2019). Also, the number of large cities with populations of over five million urban dwellers is increasing, with over thirty "megacities" with inhabitants exceeding ten million (Saaroni et al., 2018). Studies have indicated that by 2020, the developing countries of Africa, Asia, and Latin America will be home to about three out of every four urban dwellers, as well as eight of the world's nine megacities (Azunre et al., 2019). This rapid urbanization and its attendant sprawl, in both the global north and south, endangers the urban climate's long-term viability. Given that cities are among the most complex man-made systems or mechanisms, the sustainability of the urban

landscape and that of the urban dwellers is one of humanity's greatest concerns. Similarly, urban centers have emerged over the decade as critical to securing a long-term future. Economic, environmental, and social, urbanization now play a critical role in each of the three fundamental pillars of sustainability.

Rapid population growth is a worldwide phenomenon, Venter et al., (2020). The localized climatic phenomena known as the urban heat island, which is defined by higher temperatures within the city than in the rural environs, is one of the most notable environmental features bedeviling urban regions, (Saaroni et al., 2018). The intensity of this urban-rural temperature variation is impacted not only by the city's population figures, but also by its physical characteristics, such as the developed area's density, the materials used in its buildings and pavements, and the concentration of anthropogenic activities. (Elmqvist et al., 2019; Hwang et al., 2017; Noro & Lazzarin, 2015; Yao et al., 2018), Cities contribute more than 75% of national earnings, subsequently, generate about 75% of carbon emissions from global energy consumption, and are home to the majority of the world populace. Therefore, the twenty-first century should be appropriately termed the urban century, (Elmqvist et al., 2019). The Urban Heat Island is well known across cities around the world and it suffices to say that the phenomenon has spawned a plethora of literature from all regions of the globe (Noro & Lazzarin, 2015). Large surfaces of low albedo and high admittance components (primarily asphalt and concrete); reduced vegetation and pervious surfaces, which limit shade and evapotranspiration; high buildings and narrow roads, which reconfigure overall wind speeds and create urban canyons; and composition of heat-generating activities produced from combustion processes (including

cars) and other anthropogenic activities are the main factors that contribute to UHI, (Noro & Lazzarin, 2015; Wanga et al., 2015; Zölch et al., 2016).

In this urban century, Humans have transformed the cityscape into the most sophisticated and typical socio-ecological system. The fundamental challenges of government and governance will be urban. As urban planners, policymakers, and researchers navigate into the new urban environment. This is due in part to a worldwide interest in urban resilience and sustainability (Zhang & Li, 2018). One of the greatest challenges of this era is the urban heat phenomenon, though it is not new the concept (UHIE) is a more recent threat according to (Richards & Edwards, 2018) that can lead cities to become unbearably hot, with significant economic repercussions. As a result, several communities have implemented measures to limit warming, and the UHIE is becoming a critical issue in academia, (Fatma et al., 2020; Kumari et al., 2017; Li et al., 2019; Narumi et al., 2021; Yusof et al., 2017).

Many scholars have presented an enormous literature on urban agriculture. However, (Ibharim & Salim, 2020) reported that an inquiry into association between urban farming activities that enhance the well-being of urban dwellers remains unexplored, and numerous scholars have underlined the advantages of urban farming from a global urban perspective, (Kuhn et al., 2019; Li et al., 2020; Orsini et al., 2013; Vandercasteelen et al., 2018) very few highlighted the significance of urban farming in mitigating the impact of urban heat islands in our cities. Therefore, this study will highlight the potential benefits, relevance, and unique characteristics of vegetated surfaces in the form of Urban Farming

in the semi-arid region of Maiduguri Metropolis will be explored and employed to ameliorate the impact of heat island phenomena in the semiarid microclimate. (Kullu et al., 2020; Kumar et al., 2017; Li et al., 2020; Orsini et al., 2013; Yusoff et al., 2017).

Urban farming is seen by Kullu et al., (2020), as the practice of community gardening as an organizational strategy, a comprehensive approach to communities, pursuing economic growth through food production, promoting and engaging urban dwellers, improving neighbourhood safety through blight prevention, and introducing youth to intergenerational and neighbourhood interactions, advancing economic development through crop production, and encouraging independence and urban sustainability. Similarly, Rahdriawan and Arriani, (2020), reiterated that urban farming is the growing, processing, and delivery of food and other goods in municipalities and the surrounding area, as well as the recycling of land and resources and urban waste, to obtain a wide range of crops and livestock. It not only promotes local economies by producing jobs and providing access to good food, but it also significantly strengthens local microclimates by sequestering carbon and providing green spaces that add shade. Amidst miles of boring concretes and asphalt city roads, the sight of green spacing blooming an abundance of fresh fruits and vegetables is a sight to behold, which positively enhances environmental sustainability. (Filippini et al., 2018; Kullu et al., 2020; Poulsen et al., 2017; Ramaloo et al., 2018).

1.2 Background of The Study

The urban heat island phenomenon is a highly technical concept that is specific to urban climatology, engineering, and urban planning, therefore, this concept is not readily understood by a non-specialist in the field. This phenomenon has been and continues to be an important area of investigation across numerous fields of study since it was first documented nearly two centuries ago, owing to its negative impacts on the urban natural ecosystem and the overall sustainability of cities (Estoque & Murayama, 2017). Urban heat islands affect more than 54% of the world's population (UHIs). Since this phenomenon was first identified in the nineteenth century, a plethora of studies have shown that it increases the use of energy and water resources, deteriorates urban ecosystems, and threatens the health of residents (Liu et al., 2021). The urban heat island can negatively affect the urban inhabitants and disrupt the urban ecosystem and their total well-being. Also, there are no known studies that identify the formation of urban heat islands and their dynamics, and also its mitigation measures in Maiduguri Metropolis. If left unchecked this hot and dry semi-arid environment which is already fragile and vulnerable to the complex interrelationship between human activities and climatic variability will further worsen and exacerbates the negative effects of the local climate change.

According to Stewart and Mills (2016), Luke Howard's work on the Climate of London, where the science of urban heat islands was conceptualized, was the foundation of heat island studies (which was first published in 1818). For 26 years, he and his family kept a daily record of the maximum and minimum air temperatures at various sites outside



of the city to explain the climate of the area. When he examined his records to those held by the Royal Society in London, he discovered a systematic mismatch that he couldn't refute as observational inaccuracies. He concluded that the city's temperature should not be matched to the climate. His research revealed that the disparities were more pronounced during the winter season when the city was warmer, which he attributed to human heating of buildings, a lack of greenery to cool the air, and impediments to urban airflow. Steward & Mills further revealed that Before the 1970s, there were few measurements of surface temperature in cities due to the high cost and complexity of mounting thermal infrared (TIR) sensors. To examine the urban surface on a large scale, these sensors needed to be high enough to "see" a swath of the urban environment and aggregate the inputs of the ground, walls, and rooftops. TIR sensors that measure land surface temperature and allow detection of surface UHI have been included in satellite observation systems since the mid-1970s. Successive investigations in cities around the world have demonstrated that Howard's findings are applicable worldwide (Al-Marzooqi, 2019).

As Taslim et al., (2015) corroborate, Luke Howard's findings showed that the urban centre of London was 2.1°C warmer at night than the surrounding rural areas and that this warming was likely to expand by around 1°C every decade. It was not, however, classified as a heat island. When isotherms were used to model the city, the name "island" was coined. When air temperatures are depicted using isotherms, the city seems to be an island in comparison to the surrounding countryside, which has lower temperatures (Musco, 2016). The concept of "urban heat island" was coined in the 1940s to describe the difference in temperature between a city's atmosphere and the surrounding urban areas.



The sequential screen-height air temperature differential between urban and rural temperatures is commonly used to calculate the severity of the UHI. The phenomenon is an unanticipated consequence of urbanization that occurs practically in all metropolitan settings, potentially increasing energy needs and causing thermal discomfort (Wang et al., 2016).

It has been reported by numerous scholars that the most significantly influenced meteorological variable by urban growth and development is temperature. The temperature rise within cities and their environs has been well established (Santamouris, 2013; Santamouris, 2020; Stewart & Oke, 2012; Stewart & Mills, 2016; Valle-Dí'az et al., 2009). The term "urban heat island," which was first coined by Manley (1958), is now commonly accepted. The urban heat island has been examined in various cities since its conception and has been proven to cause temperature differences of several degrees between urban and rural areas (Valle-Dí'az et al., 2009). Moreover, modelling predicts that the temperature differential between urban and adjacent rural areas in some cities could reach 8 degrees Celsius by 2050. The extent of the urban heat island effect is determined by a variety of factors, including area climate, but it is projected to be greater in dry climates than in cold humid ones.

According to the World Meteorological Organization, the UHI effect can raise the air temperature in a city by 2 to 8°C (Mohajerani et al., 2017). Conversely, Santamouris, (2013) found that a more accurate range is between 5 and 15°C. The heat island effect is the result of a decline in vegetation and evapotranspiration, an increased frequency of dark

surfaces with low albedo, and greater anthropogenic heat output as our cities continue to grow and develop. In their study on heat island mitigations Santamouris et al., (2019) presented results of hundreds of cities, details on the magnitude and characteristics of the urban heat island are provided. The magnitude of UHI varies between 0.5 and 11°C, with an average value close to 4.1°C, according to data obtained through mobile traverses in 101 Asian and Australian cities. A similar record of data from 110 European cities revealed that the magnitude of UHI varied between 1 C and 10 °C, with an average maximum value of around 6°C. Looking at the findings of the above studies from West, Asia, and Australia studies on heat islands in Africa are lacking. Hence, there is the need to embark on such investigation to identify and proffer sustainable solutions to one of the most challenging climatic phenomena of the twenty-first century to keep abreast with the rest of the world for the sustainability of our cities and communities, which is one of the cardinal points of the United Nation sustainable development goals (UN SDGs).

Furthermore, changes in land use/land cover of cities can elevate the temperature of both the local air and surfaces, many degrees warmer than the surrounding locations at the same time. The interaction between human activity and the environment is characterized as LULC, and it has a significant impact on urban climate. Different UHI patterns are caused by various LULC types, which include surface material qualities such as albedo and emissivity, pollution (air), anthropogenic heating, and urban geometry, (Naserikia et al., 2019). Furthermore, various LULC features influence UHIs, including green biomass abundance, natural vegetation, desolate land, water, low/medium/high-

density built-up regions, pavements, plant abundance, and impervious surface areas, the latter two being the most influential.

Two types of urban heat islands were identified; the atmospheric urban heat islands and the surface urban heat islands. The former addresses UHI effects in the canopy or boundary layers, whereas the latter considers the surface variation in radiative temperature. In general, atmospheric urban heat islands are observed and modelled using in-situ sensors (meteorological stations or towers), radiosondes, and aircraft. Although the devices generate more reliable air UHI measurements, they are more expensive to set up (Darshana & Yuji, 2021). Similarly, pioneer studies have revealed that investigations on the development of UHIs depended heavily on meteorological measurement (in situ) data and field observation data obtained in urban and suburban regions originally studied by Howard in 1833. However, the use of remote sensing technologies can enhance the precision of defining the UHI spatial distribution and lessen the amount of time needed for analysis (Liu et al., 2021).

Rapid globalization is intrinsically linked to urbanization, city expansion, and development. Although it benefits human society greatly, it also has negative consequences for the environment. In all the environmental consequences of urbanization, the threat it poses to the thermal environment is of major concern (Darshana & Yuji, 2021; Wang et al., 2010; Yao et al., 2018). In the same vein Stewart and Mills, (2016) affirm that the urban heat island, in all its ramifications, is a common consequence of urbanization.

The temperature effect of urban environments has been investigated for almost 200 years, resulting in a vast body of knowledge with a wide range of content, spatial coverage, methodological approaches, and experimental rigour (Stewart & Mills, 2016). Similarly, Estoque and Murayama, (2017) reiterated that this phenomenon has been and continues to be an important area of investigation across numerous fields of study since it was first documented nearly two centuries ago, owing to its negative impacts on the urban natural ecosystem and the overall sustainability of cities.

The growth and development of cities, as well as industrialization, are intended to bring comfortability and well-being to city dwellers. However, amid the climate crisis, this development has resulted in various challenges as a result of human interactions in the environment. Cities' intensive anthropogenic activities consume well over two-thirds of the global energy demand and account for more than 70% of world carbon emissions. Cities, due to their complex nature and human activities, can have varied local climates that differ from the surrounding natural environment. The (UHI) effect is a well-known climate feature that occurs when urban centers are relatively warmer than their surroundings, as documented in numerous cities across the world (Wang et al., 2021b). UHI is caused mostly by the use of building materials, complex urban morphology, a lack of vegetation, and anthropogenic heat sources.

It is now a common knowledge that more than half of the world population now live in urban areas (Bassett et al., 2020; Li et al., 2019; Weng et al., 2019). In the next decade it is projected that more 60% of the world population will live in urban areas

(Ibharim & Salim, 2020). It is on record that in 1980, 1.7 billion people (39%) lived in urban areas. In 2014, the number has risen to 7.3 billion (54%) and it is projected that, the world urban population will rise to 9.7 billion (66%) by 2050. This projection indicates that more than (90%) of urbanization until 2050 will occur in Africa and Asia. Today the global urban population is expected to be growing at approximately 1.84% per year up to the year 2020, 1.63% between 2020 and 2025, and 1.44% per year between 2025 and 2030. In Nigeria 84 million people were living in cities in 2014; by 2050 it is projected to rise to 295 million (World Bank, 2016). Similarly, Bloch et al.,(2015) asserted that in Nigeria urban population has risen rapidly over the past 50 years and will continue to grow relatively fast in the coming decades. A report indicated that Nigeria has seven cities with more than a million people and Maiduguri the study area is one of them with a population of 1,112,449 people. Worldpopulationreview, (2019) Urbanization leads to the alteration of local climate and in particular creates urban heat (Folorunsho et al., 2017; Ohwo & Abotutu, 2015).

In many societies across the world, there is a growing interest in crop production in and around cities covering a variety of forms, backgrounds, and interests. There is also a correspondent increase in literature and discussions among academia and the media on the upscaling interest in Urban Farming (UF) Pölling et al., (2017), observe that, like Urban Agriculture (UA), Urban Farming is defined as 'Small-to large-scale agriculture, which mainly cultivates agricultural land on the urban fringe It is primarily economically motivated and managed by professionals with medium to large distribution networks from direct marketing to global value chains. Many scholars use different terms to explain the

agricultural practice in towns and cities, like 'urban agriculture' 'professional urban agriculture' 'professional farms' 'peri-urban agriculture' 'metropolitan agriculture' and 'urban fringe agriculture' (Opitz et al., 2016; Pölling et al., 2017). In their work, on the role of a community in urban farming activities Yusof et al., (2017) described urban farming as food or livestock production or processes that are carried out within the urban area or around the urban centres to generate income. Thus, urban agriculture in the same vein refers to the growth, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry, horticulture, aquaculture, and other practices, for producing fresh food in and around cities to feed local population (Game & Primus, 2015; Tornaghi, 2014; Yusoff et al., 2017). This definition according to Game and Primus, (2015) describes both (UPA) urban and peri-urban agriculture. The UPA was introduced by the United Nations Food and Agricultural Organization (UN FAO) as a means of planting crops and growing livestock in and around cities (FAO, 2011). It is worth noting that in Sub-Saharan Africa urban farmers contribute greatly to food security as they produce 80% of what they consume (Shabu, 2019).

The urge of humans to explore the environments and create new settlements transformed mankind's needs, which resulted in the formation of villages, towns, and cities to meet the requirements of humans regarding society, economy, culture, and comfort (Yusoff et al., 2017). As towns and cities grow and develop, there will always be consequences as a result of this urbanization to the urban environment and the urban dwellers, thus (Yao et al., 2018), in their study on surface urban heat island intensity and associated drivers in China described urban heat islands as a major detrimental

consequence of urbanization. Similarly, (Mohajerani et al., 2017) affirms that The main causes of the UHI are increased use of manmade materials and increased heat generated by human activities. As a result, it's now widely accepted that the fundamental cause of the urban heat island is growing urbanization.

1.3 Rational of the Research

The increasing number of people in our cities and towns, participating in various anthropogenic activities, combined with urbanization and industrialization, improves our material lives and comfort; however, it also causes many problems for humans, such as rising temperature, industrial effluents, and carbon emissions. Besides the negative environmental consequences, they have an impact on regional urban areas as well as local climates. Urban areas are more seriously affected by industrial activities and the heavy use of synthetic concrete structures. As a result, the natural environment and ecology have been greatly impacted, and the requisite balance has been lost (Kumar et al., 2017). He maintained that urbanization is a complex concept that is linked to some severe environmental concerns.

Similarly, it also reported that urban growth is speedily destroying biodiversity and, with it, the Earth's ability to support life on this planet. Despite the steady depletion of human civilization's fabric, the mainstream is struggling to grasp the magnitude of this loss. While there are numerous proposed solutions, their current scale of successful execution

does not match the persistent progression of biodiversity loss and other serious threats associated with continuous expansion. Significant delays between environmental deterioration and socioeconomic consequences, such as climate disruption that includes rising temperatures in cities, impede identification of the enormity of the challenging task and timely intervention required (Bradshaw et al., 2021; Yao et al., 2018). The ability of a town or city to develop a higher temperature than its surrounding rural areas is now widely recognized. This is one of the most well-documented climatological consequences of man's alteration of the urban atmosphere.

Globally, urbanization is accelerating, particularly in developing countries, where air pollution and other urbanization-related problems are becoming increasingly severe and attracting increased attention. Holistic assessments of the environmental impact of urbanization on the urban environment are necessary. This research work seeks to better understand the generation, determination, and mitigation of UHI through urban farming. The concept is intriguing and the researcher would like to learn more about it. In particular, I would like to investigate the development of the phenomenon and how urban farming can be used to mitigate the impacts in the already dry and warm critical ecosystem of semi-arid cities. The urban heat island phenomenon which is one of the major negative effects of urbanisation, refers to higher temperatures in cities than in rural areas. UHIs have several negative effects on natural ecosystem (for example, net primary production), human health (for example, worsening respiratory disease and even fatal consequences), and the urban landscape (e.g. pollution) (Yao et al., 2018).

The ability of a town or city to develop a higher temperature than its surrounding rural areas is now widely recognized. This is one of the most well-documented climatological consequences of man's alteration of the urban atmosphere (Chen et al., 2006; Waffle et al., 2017; Weng, 2009). According to emerging literature, UHI dynamics are more complex and difficult for dryland cities, which include arid, semi-arid, and Mediterranean climates. Although many studies focus on temperate regions, there are far fewer that emphasize dryland regions, and even fewer that do a worldwide correlation (Dialesandro et al., 2019). This assertion by Dialesandro et al that dry regions experience even more complex challenges than other areas makes it imperative for the researcher to embark on this endeavour as the study area is coincidentally situated in the dry semi-arid region of West Africa to understand the dynamics of the phenomenon.


Consequently, after looking at length on some available literature from multiple sources and some interactions with some critical stakeholders within the research community, the researcher chose to focus on these three distinct areas. First, the researcher will look at the formation of the phenomenon to identify and establish its status. Secondly, the study will look at the trend, pattern and or magnitude of the concept. Finally, this piece of work will aim to explore how urban farming can help ameliorate the impact of urban heat island. Numerous sources of databases will be utilized, though a primary source of data will be acquired directly in the field, the study is hinged on remote sensed data from USGS.

According to a study in one of the Asian cities revealed that, the occurrence of the UHIs and SUHIs is commonly associated with urban sprawl and increased industrial and human activity; however, geographical location, climatic condition, urban materials, seasonal changes, and times of day and night can all have differential influences (Haashemi et al., 2016). This finding suggests the need to identify the complexities of the phenomenon in various parts of the globe and provide appropriate measures required by them for the sustainability of cities, as it is evident that each environment is with its own peculiarities. A study on urbanization's contribution to climate warming in Great Britain, by Bassett et al., (2020) also agrees with Haashemi's statement, reaffirming that, UHI research is mainly limited to the city of interest.

Numerous regions are grappling with the urban heat Island effect, and so much research has been devoted to improving those conditions. Several scholars have discussed vegetation as part of mitigating factor, but few studies have proposed using it, especially in the west African sub region. This study looks into the potential for growing food crops and urban farming in general in hot urban microclimates of this area as a heat island mitigation strategy. According to UN Habitat's report on the state of African cities with the theme "Re-imagining sustainable urban transitions," the UN body highlighted that, in 2011, West Africa's total urban population was 140.1 million (44.9%). The sub-region was indeed projected to reach an urban majority of 196 million residents shortly after 2020. After Eastern Africa, Western Africa is the continent's fastest urbanizing region. The West Africa's population is expected to rise from 49.9% in 2020 to 65.7% by 2050. As a result, all countries in the sub region are confronted with accelerating city growth rates and the

resulting increase in demand for affordable housing and all basic amenities (UN-Habitat, 2014). As a result, it increases the pressure on the critical urban ecosystem and the scarce resource, with negative environmental consequences. This threat to the urban environment and its inhabitants must be addressed immediately.

Western Africa is one of the world's poorest, least urbanized and least industrialized sub-regions (Ofoezie et al., 2022; UN-Habitat, 2014). In the region and the whole of Africa Nigeria is the most populous country, this as a result of its share number, may also have serious consequences for regional urbanization estimates and the environment (UN-Habitat, 2014).

 05-4506832 With nearly all of the world's demographic growth concentrated in developing nations, rising urban population is becoming a defining characteristic of the developing world. As useful as they are as demographic absorbers, metropolitan regions create complex and multifaceted problems on unprecedented scales. The consequences of this population dynamics, particularly in African cities, resulted in threats that are quite difficult to embrace. Most major African cities, including those in Nigeria, are dealing with severely compromised physical and living conditions. Informal settlements, urban sprawl, and squatter settlements are examples of deterioration, as are increased temperatures, traffic congestion, flooding and erosion, deteriorating infrastructure, and shortfalls in service delivery (Olujimi, 2009).

Man continues sustenance on Earth, and the quality of his life is heavily influenced by the environment. The major environmental components-air, water, and land-are man's supporting pillars, on which he relies directly or indirectly for his survival and well-being. However, man appears to be at conflict with his environment, as evidenced by overuse and ineffective management of the environment's basic components. This unsustainable exploitation of the natural environment as a result of anthropogenic activities has created significant challenges and a substantial threat to Nigeria's biophysical environment including the urban micro climate and particularly rising urban temperatures (Ohwo & Abotutu, 2015).

The advent of cities and other large metropolitan areas in developing nation takes a different trajectory than the developed world experience. While urbanisation in developed countries is the result of massive industrialization and quite well urban planning management system, the situation in the poorer countries, including Nigeria, is the result of "urban involution," or the advent of cities as a result of mass migration from rural areas to "assumed cities" that lack sufficient plan, design, infrastructural facilities, basic amenities, sanitary conditions, and a structure of economic systems to provide the for need of the urban dwellers (Udoh et al., 2020).

Nigeria's urbanization and urban population have increased significantly in the last 20 years and the trend is expected to continue (Ezeudu, 2020). Similarly, it has also been observed that, Since the second half of the twentieth century, the rate of urbanisation has been increasing dramatically. The environmental impact of urbanisation has attracted a lot

of attention (Ikporukpo, 2018). Most cities in Nigeria, have expanded in an uncontrolled and unsupervised manner, resulting in a variety of environmental issues such as overcrowding, heavy traffic, carbon emissions, unstable housing, unemployment, urban blight, and deterioration of urban amenities (Ezeudu, 2020; Ikporukpo, 2018; Olujimi, 2009). Basically, it further worsens the already fragile urban climate as well as other existential threats in the cities often these cities' operation, togetherness, wellbeing, and sustainability are in doubt. The preceding has prompted concerns and calls from various groups and stakeholders in the built environment for progressive changes in policies, laws, technologies, and development strategies aimed at improving urban quality (Udoh et al., 2020). These can only be attained by objectively understanding the dynamics of these challenges through novel research and effective implementation of the findings and also

 05-4506832 by engaging all stakeholders.

Furthermore, the study revealed that, since 2010, the Nigerian urban population has been rapidly increasing, and it is expected to reach nearly 300 million by 2050. This rapid increase in urban population in Nigeria has resulted in what is known as "false urbanisation," a situation in which urban growth outpaces economic growth and increasingly outpaces the ability of the country's healthcare systems to provide reasonable and relevant care. Slums, overcrowding, indecent shelter, heavy traffic, open dumpsites in city centers, job losses, flooding, infrastructural decay, and general decline in the standard of living of urban inhabitants are all manifestations of false urbanisation in Nigeria. All of these functions and procedures aggravate the already fragile urban ecosystems and, in

particular, the urban microclimate by raising the temperature of the atmosphere, necessitating immediate action (Udoh et al., 2020).

This is the unique case of the study area, which has been devastated by the decade-long Boko Haram insurgency that has severely damaged the region, with Maiduguri being the worst hit area as the epicentre of the violent conflict. As a result, all nearby towns and villages have been forced to migrate into the Metropolis, threatening the already stressed urban ecosystem beyond limits. Therefore, it is critical that a study that seeks to understand the dynamics of this environment's microclimate be conducted, especially in the wake of rising urban temperatures, which can result in several unintended consequences for the urban inhabitants and the environment.

1.4 Statement of problem

Rapid urbanization over the past few decades has resulted in a significant decrease in urban vegetation cover (VC), raising land surface temperature (LST) and making the environment less sustainable. Urban green space is one of the most crucial elements in promoting ecological balance and environmental sustainability (Rahaman et al., 2022). Urban sprawl is gradually displacing these green spaces, which speeds up carbon emissions, increases land surface temperature, and leads to global warming (Kafy et al., 2021; Santamouris, 2020; Tian et al., 2021; Yu et al., 2020).

Many studies have shown that increasing LST significantly contributes to local, regional, and global warming impacts, paving the way for the global emergence of the Urban Heat Island problem. The UHI is a well-documented consequence of urbanization, defined as higher temperatures in city areas as compared to surrounding rural areas (Hwang et al., 2017; Imran et al., 2019; Mohd et al., 2019; Oke, 2006; Rahaman et al., 2022; Santamouris, 2013; Schatz & Kucharik, 2014; Yao et al., 2019). Current empirical results from Asia, Europe, the United States, Africa, and Amazonia demonstrated that lower vegetated surfaces eventually led to global-scale warming and were linked to a rise in LST (Rahaman et al., 2022). This critical situation hastens the dire environmental consequences by undermining local societies' sustainability in the face of massive urbanization and contributing to significant local and global climate changes (Beaumont et al., 2022; Rahaman et al., 2022; Santamouris, 2020).

The UHI effect can worsen health effects by altering the micro-climate in the city, and rainfall patterns, interacting with air pollution to make it worse, elevating the risk of flooding, and reducing water quality. Exposure to higher temperatures is the UHI's most significant influence on human health (Aflaki, et al, 2017; Heaviside et al., 2017; Ningrum, 2018; Santamouris, 2020). It plays a significant role in the worsening of the effects of global warming (Aflaki, et al, 2017), and climate change (Beaumont et al., 2022; Santamouris, 2020). Furthermore, the adverse health effects of heat exposure range from the escalation of minor health conditions to an elevated risk of increased morbidity and mortality. Heat is frequently a contributing factor to deaths and morbidity from other causes, such as respiratory illness, rather than being the only cause of death from heat



stroke. Although health effects are most serious when temperatures are extremely high or during heat waves, this threat has been observed to be substantial at even moderately high temperatures (Heaviside et al., 2017; Santamouris, 2020).

In its State of the Climate in Nigeria report, the Nigerian Meteorological Agency (NiMet) remarked that Maiduguri recorded temperatures of 45.8 °C in 2019 and 2020 and 43.9°C in 2021 (NiMet, 2022). Similarly, the agency NiMet, in its high-temperature outlook signed by the Director-General, Prof. Mansur Matazu, predicted that most Northern cities would experience temperatures ranging from 35°C to 40°C. However, Borno state is expected to have temperatures above 40°C. The report further states that Maiduguri is likely to experience high thermal discomfort (Falaju, 2022; Gabriel, 2022; Yakubu, 2022). Furthermore, the trend continued this year as the highest temperature value in the nation was recorded in Maiduguri in April at 43.9°C. Maiduguri endured this severe condition for 69 days with a daytime temperature greater than 40°C. During this period, over 475 suspected cases of Measles were reported in 22 states from January to June. (NiMet, 2022). The same report indicated that high temperatures leading to extreme weather events have resulted in the prolonged heatwave in March, April, and May across Nigeria and the Nigerian Centre for Disease Control (NCDC) recorded.

Similarly, the NCDC recorded Cerebrospinal Meningitis - 175 suspected cases with 11 confirmed cases and 3 fatalities. Measles - 17,541 suspected cases, with 816 confirmed and 204 fatalities. Malaria - is one of the leading causes of illnesses and deaths in Nigeria. The (WHO) reports that Nigeria accounted for 27% of the Malaria cases and 23% of deaths



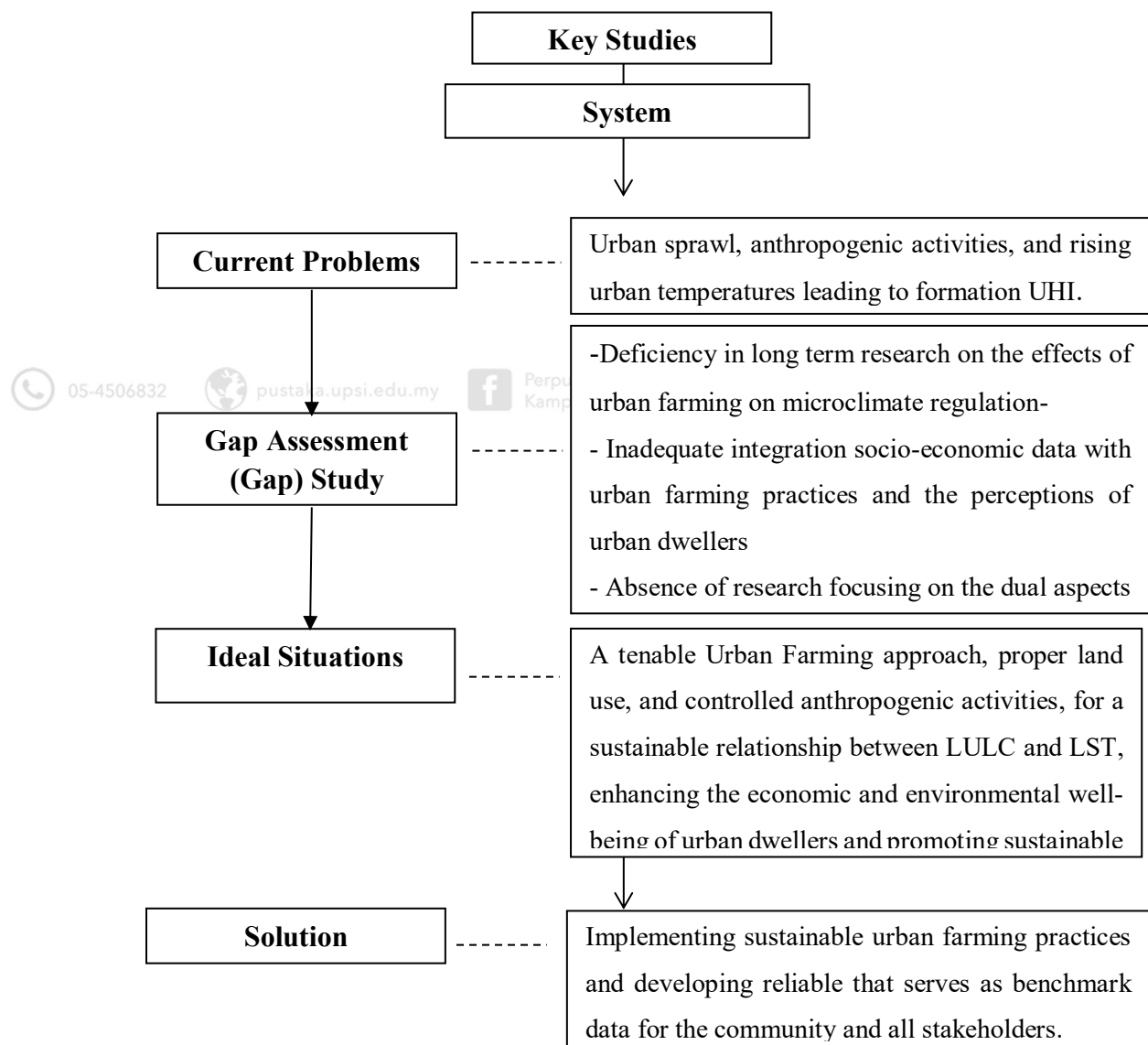
due to Malaria Globally. It is estimated that Nigeria loses up to one billion USD yearly due to Malaria-related absenteeism and production losses (NiMet, 2022). Urban sprawl and rising temperatures have been linked to food insecurity and health issues such as meningitis, discomfort, and heat stroke. Therefore, is essential not only for regulating the urban microclimate but also for providing food and promoting a healthier life for city residents (Carolan, 2020; Nkwocha et al., 2020; Grebitus et al., 2020; Hairy et al., 2020). NiMet, (2022) also corroborated and warned about acute food insecurity in this region, a report by the agency shows that 12.9 million people were in severe acute food insecurity between (October – December 2021) of whom two million are in Adamawa, Borno, and Yobe states. These figures are projected to increase to 18 million and 3,5 million, respectively, during the peak of next year's rainy season (June to August 2022), including 13,550 people likely to face catastrophic conditions if food assistance along with resilience interventions are not urgently intensified and sustained (NiMet, 2022).

Despite rising urban temperatures and obvious evidence of fast land use change in Maiduguri, no previous research has specifically recognized, evaluated, or mapped the city's UHI, leaving a significant gap in localized climatic knowledge. Urban farming has grown informally in response to socioeconomic pressures, but its impact in alleviating UHI and regulating microclimates has not been investigated empirically using geospatial analysis. Existing research rarely combines biophysical data (e.g., LST, plant cover) with socioeconomic factors like community perception and land-use behaviour. There is also a scarcity of research that examines urban farming as a dual instrument for livelihood support and environmental regulation. This study aims to fill crucial gaps by conducting long-

term UHI analysis in Maiduguri, integrating urban farming trends with cooling effects and community perspectives to support sustainable urban development.

Figure 1.1

Research gap





Numerous strategies have been examined to minimize the impacts of UHI on cities worldwide. Urban vegetation, a form of urban farming, is crucial for enhancing human thermal comfort within cities. Researchers in Melbourne, Australia, found that street trees can lower the daytime Universal Thermal Climate Index (UTCI) by 6 degrees Celsius during the summer, reducing thermal stress from very strong (UTCI > 38 °C) to strong (UTCI 32 °C) (Imran et al., 2019). The same study further reports that urban vegetation reduces UHI and improves human thermal comfort (HTC) during the day in Melbourne, especially during heatwaves. However, due to lower ground/storage heat flux at night and minimal cooling during the day, the combination of urban vegetation and cool roofs provides the maximum cooling benefit. Similarly, Taher et al., (2019) report that Urban vegetation is much more than just an extravagance or an improvement in aesthetics for cities. It should be regarded as an essential component of urban planning. Due to the evapotranspiration process and the reduction of surface temperatures between 5 to 20 °C due to shading, urban greenery such as trees and parks was proposed as an effective way to improve the harsh urban climates through building structures within the local or regional scale.

Taher et al., (2019) in the same vein highlighted those other strategies used to include urban farms which are used in Europe, cool roofs that are used in California, large urban gardens used in Singapore, and central parks used in New York. It is amazing how different, intricate, and diverse possible adaptation strategies cities provide in response to population growth and climatic changes. To reduce UHI. Others include phase-changing materials and reflective pavements. Also, the effects of rice and soybean



cultivation and the urban garden on UHI were assessed and were found to be effective (Guo-yu et al., 2013). Conversely, in their study on temporal temperature variation in urban gardens Nolte et al., (2022) observed that urban environments have a significant impact on the night-time temperature range, and the inner composition of gardens does not have the same impact on temperature regulation as the composition of the surrounding landscape. In particular, for vulnerable populations where bioclimatic stressors are most severe, these results point to the potential for using urban gardens as green infrastructure to develop cooling islands within the impervious landscape.

For these reasons, academia, city planners,' policymakers, and development partners are paying more and more attention to the connection between land use and the urban environment as they work to identify, create, and ultimately implement growth strategies that aim to improve the well-being of urban populations. Maiduguri the study area with its current estimate at over one million urban dwellers, the city's population continues to rise (Abdul-Azeez, 2018; Nkwocha et al., 2020). Consequently, this leads to environmental challenges such as the urban heat island effect among others. There are enormous studies on heat islands in the global north and south. However, it is pertinent to note that, an investigation that specifically explores the impact of the urban heat island in Maiduguri and its environs remains unexplored. Hence, a better understanding of the mechanism leading to the development of the phenomenon is required to develop and implement a mitigation measure that the researcher believes could be found, among others, in urban farming.

Therefore, this study intends to evaluate the potential of urban farming which is part of the green infrastructure (areas with a high concentration of vegetation) in mitigating the impact of urban heat islands and ultimately minimizing its effect on the environment and its impact on the urban dwellers such as the risks of heat-related illness from high urban temperatures especially among the most vulnerable populations (e.g. children and aging population and many with chronic health conditions, impoverished or otherwise disadvantaged minorities). By providing adequate details on the status, causes, and effects of urban heat islands, the study will be of great significance. Moreover, the potential contributions of urban farming to the control of the urban microclimate. This will act as a framework for the government, academic institutions, urban farmers and residents, urban planning board, engineers, architects, other field researchers, development partners, and all other stakeholders who are concerned with the sustainability of the urban landscape and its inhabitants, in particular to those who are concerned with urban climate. The study will primarily focus on Maiduguri and its surroundings, as well as portions of the Jere, Konduga, and Mafa local governments.

1.5 Aim of the study

This study aims to identify and assess the Spatio-temporal dynamics of the urban heat island phenomenon in Maiduguri Metropolis and its environs.

1.6 Objectives of the study

The specific objective of the study is to:

- i. Determine the level of urban farming practice and the phenomena of the urban heat island of Maiduguri between 1992 to 2022.
- ii. Analyze the spatiotemporal trends and the magnitude of Land Surface Temperature and Land Use Land Cover changes in Maiduguri between 1992 and 2022.
- iii. Examine the urban residence knowledge and perceptions of urban heat islands and their mitigation through urban farming.
- iv. Determine the effectiveness of urban farming as a mitigation approach to reduce the impact of urban heat islands in Maiduguri.

1.7 Research Questions

- i. What is the extent of evolution in urban farming practices, and what are the characteristics of the urban heat island effect in Maiduguri over the past three decades?
- ii. What are the spatiotemporal trends and magnitudes of land surface temperature and land use/land cover changes in Maiduguri between 1992 and 2022?
- iii. What is the level of knowledge and what are the perceptions of urban residents in Maiduguri regarding urban heat islands and their potential mitigation through urban farming?

- iv. How effective is urban farming as a mitigation strategy in reducing the impact of urban heat islands in Maiduguri?

1.8 Scope of the study

The study examined the spatio-temporal dynamics of the Urban Heat Island in Maiduguri metropolis, Borno state, North Eastern Nigeria, from 1992 to 2022, as well as the possibilities for urban farming to minimize its effects on the environment and rural residents. It encompassed Maiduguri and its surroundings, as well as portions of the local governments of Jere, Konduga, and Mafa. A quantitative technique was implemented, including remote sensing and GIS analysis. An environmental model (ENVI-met) was used to analyze urban farming's potential for UHI mitigation, and Google Earth Pro was utilized to track the growth of urban farming practices. A survey of 400 urban inhabitants was also undertaken to collect information on their socioeconomic status and awareness of UHI.

1.9 Operational Definition

Urban Heat Island

Urban Heat Island refers to the spatial variation in land surface temperatures between densely built-up urban areas and adjacent vegetated or less-developed zones within Maiduguri. This phenomenon is quantified using satellite-derived thermal data, producing

continuous raster surfaces that facilitate the assessment of UHI intensity and its temporal distribution across the urban landscape.

Urban Farming

Urban farming refers to the practice of cultivating crops, engaging in horticultural activities (including the growth of fruits, vegetables, and ornamental plants), and planting or maintaining trees within the urban boundaries of Maiduguri. These activities are conducted in various urban spaces such as home gardens, vacant lots, community gardens, and along streets or riverbanks. Urban farming serves multiple purposes, including enhancing food security, promoting environmental sustainability, and contributing to the urban green infrastructure. By increasing vegetation cover, urban farming plays a significant role in mitigating the UHI effect, improving air quality, and fostering ecological balance within the city.

Urban Heat Island Mitigation

Urban Heat Island Mitigation refers to the reduction of elevated urban temperatures through the implementation of urban farming practices within Maiduguri's urban landscape. Urban farming activities including the cultivation of crops, horticulture, and tree planting in spaces such as home gardens, vacant lots, community gardens, and along streets or riverbanks serve as green infrastructure that enhances vegetation cover. This increased greenery facilitates natural cooling processes like evapotranspiration and shading, thereby lowering land surface temperatures and alleviating the UHI effect.

Green Infrastructure

In this study, green infrastructure refers to natural and human-managed vegetative systems that contribute to urban environmental quality, particularly temperature regulation. Urban farming is treated as a key form of green infrastructure, with its cooling potential assessed through its spatial extent and vegetation density. The distribution and effectiveness of these green spaces are quantified using satellite-derived vegetation indices, primarily the Normalized Difference Vegetation Index, to evaluate their role in mitigating UHI effects across Maiduguri.

Land Surface Temperature

Land Surface Temperature is operationally defined in this study as the temperature emitted from the Earth's surface, captured through thermal infrared satellite sensors (e.g., Landsat 4, 7, and 8). LST is used as the primary indicator of surface heat conditions across Maiduguri and is analyzed to detect urban heat patterns. Variations in LST across different land uses, especially between urban farming zones and built-up areas, are used to evaluate the cooling impact of vegetation and assess the severity of the UHI phenomenon.

Normalized Difference Vegetation Index

Normalized Difference Vegetation Index is a satellite-derived indicator used to measure the presence, density, and health of vegetation cover. In this study, NDVI is applied to analyze spatiotemporal changes in vegetation in Maiduguri from 1992 to 2022, serving as a proxy for green infrastructure and contributing to the assessment of vegetation's role in UHI mitigation.

1.10 Significance of the Study

The advent of the urban century brings with it a unique set of concerns. The urban population now exceeds more than half of the world's population (Bassett et al., 2020; Bloch et al., 2015; Hussain et al., 2019; Ulpiani, 2021; Yao et al., 2018). Among the challenges of this era is the urban heat island phenomenon, which may be largely attributed to urbanization, population growth, and climate change (Meriam et al., 2019; Singer, 2022; Weng, 2018). The state of this urban environment is extremely important to everyone. The sustainable development of cities and communities, as one of the 17 United Nations Sustainable Development Goals, should be regarded as an essential component of the approach to combating UHI and addressing climate change (Echendu, 2020; Tian et al.,

Under a warming climate and an increasingly growing urban environment, the UHI effect and its impacts are projected to be more significant. This is especially true in China, India, and Nigeria, where the urban population is expected to account for 35% of the world by 2050 (Martin-Moreau & Ménascé (dir.), 2019; Zhou et al., 2019). Despite all the commitment by government and scholars across the global north and south as demonstrated by the array of literature available on the concept of the urban heat island, there has not been an inquiry highlighting the phenomenon of urban heat island effects and its impact on human and the environment in (Maiduguri) the study area and its environs. Therefore, this study aims to identify the urban heat island phenomenon and its impacts on the urban populace. It is also expected to examine the existing urban farming practices as a mitigating

strategy on the consequences of the urban heat island effect. The findings of the study will serve as a baseline for reference for urban planners, academia, policymakers, and all stallholders concerned with the sustainability of the delicate urban environment. Appropriate mitigation and adaptation strategies to reduce the UHI intensity to improve urban sustainability will also be highlighted by the findings. The study will help in no small measure by providing sufficient information on the causes and effects of urban heat islands, will serve as a framework for the government, urban farmers/dwellers, urban board planners, engineers, architects other field researchers, development partners and all stakeholders that are concerned with the sustainability of the urban landscape and its inhabitants and specifically to those who are concerned with urban climate. Primarily, the study will cover Maiduguri and its surrounding area, parts of Jere, Konduga, and Mafa

1.11 Summary

The foundation for a thorough investigation of the Urban Heat Island (UHI) phenomenon in Maiduguri, Nigeria a semi-arid region with hot, dry weather has been established in this Chapter. The dearth of empirical research on urban heat islands (UHI) within this complex environmental framework highlights the importance of this study, establishing it as a fundamental baseline for every stakeholder engaged in urban planning, environmental sustainability, and community welfare. This study aims to provide important insights into the dynamics of UHI by clearly defining its objectives and research questions. It focuses

on the spatiotemporal aspects of changes in Land Surface Temperature and Land Use/Land Cover from 1992 to 2022. Because of Maiduguri's distinct environmental conditions including its pre-existing hot and dry climate addressing rising temperatures presents additional challenges. For the region's resilience and sustainable development, investigating UHI mitigation strategies is therefore even more important.

In addition to offering a historical context, a spatiotemporal analysis of UHI in Maiduguri will lay the groundwork for comprehending the extent and current impact of the UHI effect in the area. Furthermore, the evaluation of urban farming as a viable mitigation strategy presents a novel way to deal with the issues raised by UHI and provides a long-lasting, neighbourhood-focused resolution. This study acknowledges the significance of assessing urban dwellers' attitudes and knowledge about UHI and urban farming. A thorough assessment of the complex elements of UHI mitigation is made possible by the research's addition of a social dimension through the inclusion of public awareness and engagement.