DSpace Institution

DSpace Repository **http://dspace.org**

Geography and Environmental Studies Thesis and Dissertations

2026-05

The Interplay of Urban Expansion, Climate Governance, and Peri- Urban Livelihood: The Case of Bahir Dar City, Northwest Ethiopia

Mastawal, Melese

http://ir.bdu.edu.et/handle/123456789/17055

Downloaded from DSpace Repository, DSpace Institution's institutional repository

BAHIR DAR UNIVERSITY

FACULTY OF SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

THE INTERPLAY OF URBAN EXPANSION, CLIMATE GOVERNANCE, AND PERI-URBAN LIVELIHOOD: THE CASE OF BAHIR DAR CITY, NORTHWEST ETHIOPIA

BY

MASTAWAL MELESE EJIGU

MAY, 2026

BAHIR DAR, ETHIOPIA

BAHIR DAR UNIVERSITY

FACULTY OF SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

The Interplay of Urban Expansion, Climate Governance, and Peri-Urban Livelihood: The Case of Bahir Dar City, Northwest Ethiopia

By

Mastawal Melese Ejigu

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Geography and Environmental Studies (Specialization in Socio-Economic Development Planning and Environment)

Advisors

Mesfin Anteneh Wubie (PhD, Associate Professor)

Simachew Bantigegn Wassie (PhD, Assistant Professor)

May, 2026

Bahir Dar

© 2026 Mastawal Melese Ejigu

Dedication

I dedicate this work to my father, the late Melese Ejigu, my first teacher and lifelong inspiration. His profound commitment to education, exemplified by a lifetime of service and quiet sacrifice for his family, is a firm spirit that guided this research to completion.

This dissertation is a testament to his philosophy of lifelong learning.

Declaration

I hereby declare that this Ph.D. dissertation entitled “The Interplay of Urban Expansion, Climate Governance, and Peri-Urban Livelihood: The Case of Bahir Dar City, Northwest Ethiopia” is my work and has not been submitted to any other university for the award of any degree. Moreover, all the sources used in the study are properly acknowledged and cited.

Mastawal Melese Ejigu 10/06/2026 Bahir Dar

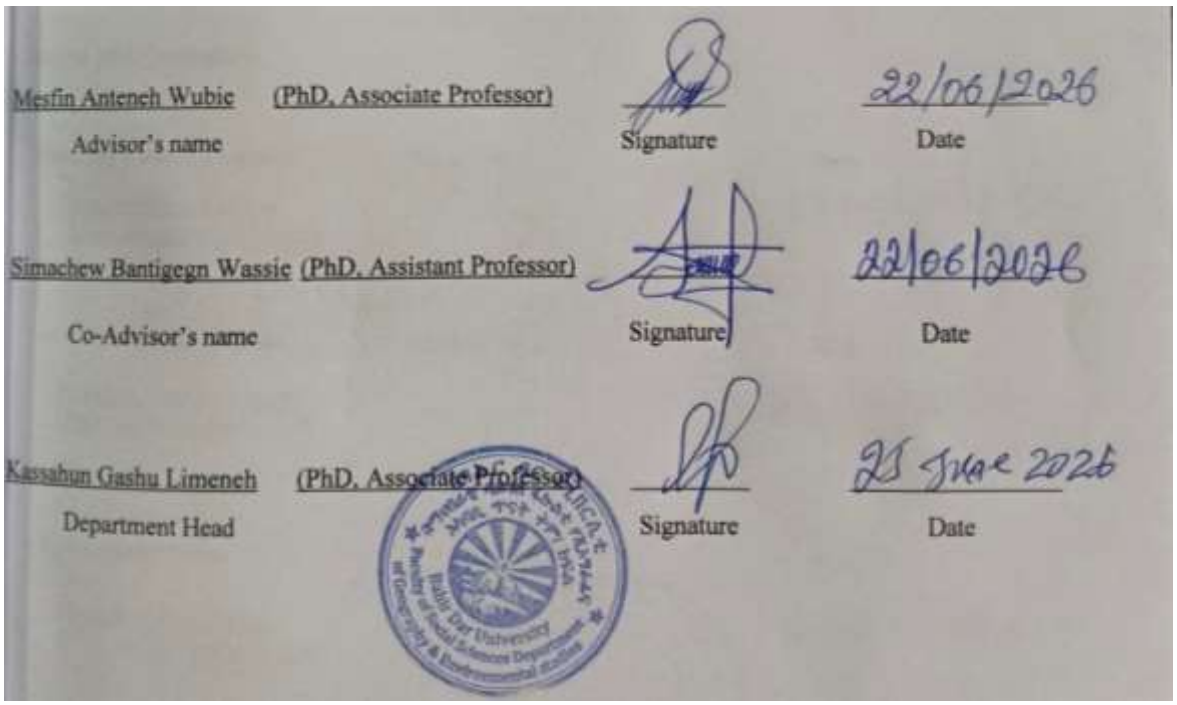
Bahir Dar University

Faculty of Social Sciences

Department of Geography and Environmental Studies

Approval of Dissertation Defence

I hereby certify that I have supervised, read, and evaluated this dissertation titled "The Interplay of Urban Expansion, Climate Governance, and Peri-Urban Livelihood: The Case of Bahir Dar City, Northwest Ethiopia" by Mastawal Melese Ejigu prepared under my guidance. I recommend the dissertation be submitted for oral defence.



Bahir Dar University

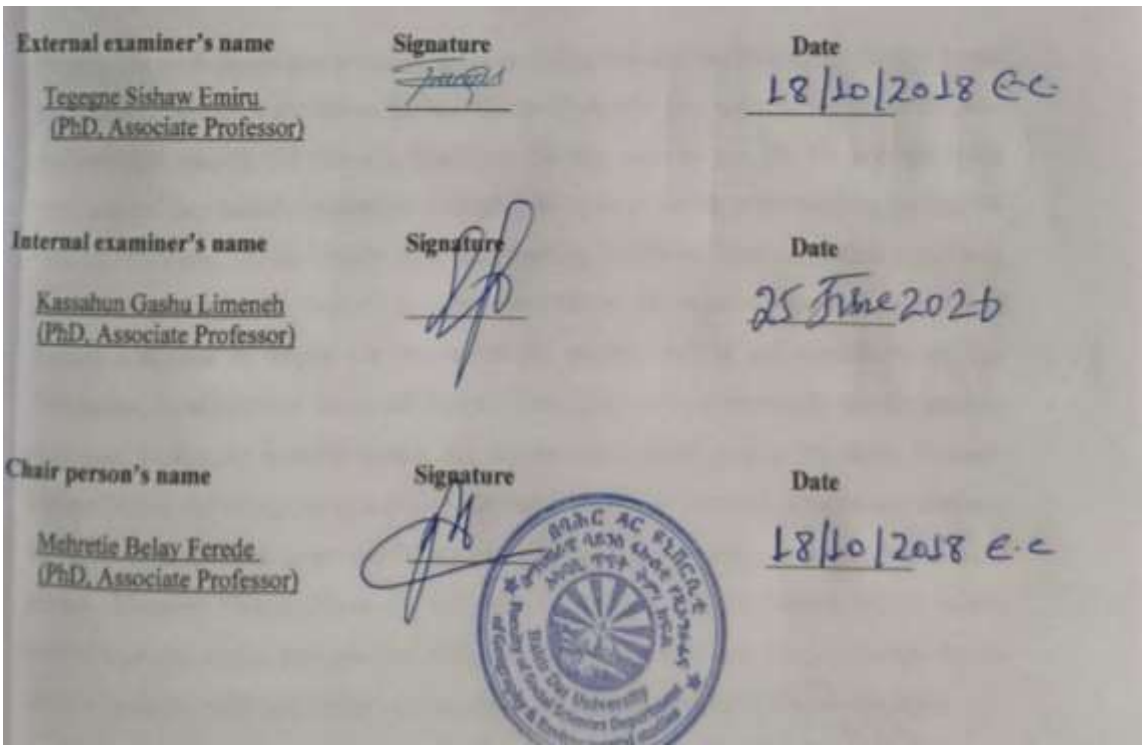
Faculty of Social Sciences

Department of Geography and Environmental Studies

Approval of Dissertation for Defence Result

As members of the board of examiners, we examined this dissertation entitled "The Interplay of Urban Expansion, Climate Governance, and Peri-Urban Livelihood: The Case of Bahir Dar City, Northwest Ethiopia" by Mastawal Melese Ejigu. We hereby certify that the dissertation is accepted for fulfilling the requirements for the award of the degree of "Doctor of Philosophy in Geography and Environmental Studies (Specialization in Socio-Economic Development Planning and Environment)".

Board of Examiners



ACKNOWLEDGEMENTS

This dissertation would not have been possible without the guidance and unwavering support of my advisors, Dr. Mesfin Anteneh and Dr. Simachew Bantigegn. I am grateful for their intellectual mentorship, insightful critiques, and constant encouragement, which have shaped this study from its start to its final form. Their patience, wisdom, and persistent belief in my potential were helpful in this program. I extend my sincere appreciation to my host institution, Bahir Dar University, for providing me with the academic home, financial support and scholarly environment necessary to pursue this research. I am equally indebted to my home institution, Debre Markos University, for its generous financial support, which was indispensable for the successful completion of my study.

My journey was also enriched by the collegial and intellectually stimulating atmosphere within the Department of Geography and Environmental Studies at Bahir Dar University. I am grateful to all the staff members and my fellow PhD students and/or friends for their friendship, support, and the many insightful discussions that have broadened my academic horizons. A special note of thanks goes to my dear friend, Dr Tsebelu Abayneh, whose constant encouragement and belief in me were a source of motivation during the most challenging times.

Finally, this work stands as a testament to the unending love and sacrifice of my family. I owe my deepest gratitude to my father, the late Melese Ejigu, who was not only my father but also my very first teacher, the one who taught me the first letter of my life. He exemplified a profound and firm belief in education, dedicating 41 years of his life to the teaching profession until his retirement. His philosophy of lifelong learning and his steadfast conviction in my own educational journey were constant sources of inspiration. He remains a guiding light whose support continued to inspire me throughout my journey and in the completion of this dissertation. To my mother, Fentanesh Belete (Nane), the source of my energy and my greatest champion, I offer my heartfelt thanks. My sincere appreciation goes to my sister, Netsanet Melese (Hasu), for always being a pillar of strength, and to her husband, Almzewude Berihun, for his keen interest and for always following my progress. My thanks are also extended to my brother, Muluken Melese (Wodivic), and to my little sister, Hiwot Melese (Mita), whose worries and care always reminded me of the love that surrounded me. The joy brought by my sister's children, Aliab and Nolawi Almzewude, provided wonderful moments of respite.

TABLE OF CONTENTS

Contents

ACKNOWLEDGEMENTS vi
TABLE OF CONTENTS vii
LIST OF TABLES xii
LIST OF FIGURES xiii
ABBREVIATIONS/ACRONYMS xiv
ABSTRACT xvi
CHAPTER 1 1
1. INTRODUCTION 1
1.1. Background of the Study 1
1.2. Statement of the Problem 3
1.3. Objectives of the Study 7
1.3.1. General Objective 7
1.3.2. Specific Objectives 7
1.4. Research Questions 7
1.5. Significance of the Study 7
1.6. Scope and Delimitations of the Study 8
1.7. Theoretical and Empirical Evidence of the Study 10
1.7.1. Conceptualizing the Urbanization, Land Use, and Climate Nexus 10
1.7.2. Theoretical Frameworks for Governance 11
1.7.3. Theoretical Perspectives of Livelihood Vulnerability 13
1.7.4. Conceptual Framework 16
1.8. Philosophical Foundation of the Study 17
1.8.1. Research Approach and Design 19
1.9. Organization of the Dissertation 20
REFRENCES 21
CHAPTER 2 28

2. URBANIZATION AND LAND SURFACE TEMPERATURE DYNAMICS IN BAHIR DAR, ETHIOPIA: A COMPARATIVE ANALYSIS OF PRE- AND POST-CAPITAL STATUS 28
Abstract 29
2.1. Introduction 30
2.2. Methods and materials 32
2.2.1. Study area description 32
2.2.2. Data Sources and Collection Tools 33
2.2.3. Methods of Data Analysis 34
2.3. Results and Discussion 39
2.3.1. Land Use-Land Cover Changes and Urban Expansion 39
2.3.2. Land surface temperature trends in Bahir Dar city (1984 - 2024) 42
2.3.3. LST Changes Associated with Bahir Dar's Capital Status 46
2.3.4. Land Use Indices 48
2.3.5. Correlation between LST and land use indices 51
2.4. Conclusion 53
2.4.1. Limitations and Future Directions 53
REFRENCES 54
CHAPTER 3 63
3. EVALUATING INSTITUTIONAL EFFECTIVENESS IN URBAN CLIMATE GOVERNANCE: THE CASE OF BAHIR DAR CITY, NORTHWESTERN ETHIOPIA 63
Abstract 64
3.1. Introduction 65
3.1.1. Theoretical Framework for Evaluating Institutional Effectiveness in UCG 68
3.2. Methods and materials 70
3.2.1. Study area description 70
3.2.2. Research Approach and Design 72
3.2.3. Methods of Data Analysis 76

3.3. Results and Discussion 79
3.3.1. Reliability Analysis of UCG Indicators 79
3.3.2. Accountability in Urban Climate Governance 80
3.3.3. Participation in Urban Climate Governance 82
3.3.4. Equity in Urban Climate Governance 84
3.3.5. Awareness-Raising in Climate Change Governance 87
3.3.6. Institutional Capacity in Climate Change Governance 89
3.3.7. Adaptability in Climate Change Governance 91
3.3.8. Climate Change Law and Enforcement 93
3.3.9. Inferential Analysis and Perceptual Gaps across Governance Levels 96
3.3.10. Overall Effectiveness of UCG in Bahir Dar 97
3.4. Conclusions and Policy Recommendations 98
3.4.1. Synthesizing the Governance Deficit in Bahir Dar 98
3.4.2. Policy Recommendations 100
3.4.3. Limitations and Future Directions 102
REFRENCES 103
CHAPTER 4 112
4. INSTITUTIONAL CONSTRAINTS ON EFFECTIVE URBAN CLIMATE GOVERNANCE IN BAHIR DAR CITY, ETHIOPIA 112
Abstract 113
4.1. Introduction 114
4.1.1. Theoretical Framework (Institutional Capacity as a Precondition for Adaptive Governance) 115
4.1.2. Research Hypotheses 117
4.2. Methods and Materials 117
4.2.1. Study area description 117
4.2.2. Research Approach and Design 119

4.2.3. Methods of Data Analysis 124
4.3. Result 126
4.3.1. Exploratory Factor Analysis 126
4.3.2. Confirmatory Factor Analysis (The Measurement Model) 129
4.3.3. Structural Equation Modeling (Testing the Structural Relationships) 132
4.4. Discussion 136
4.4.1. Human Resources and Institutional Capacity 136
4.4.2. Deficiencies in Policy and Regulatory Frameworks 137
4.4.3. Political Will and Leadership Instability 139
4.4.4. Financing and Budget Allocation 140
4.4.5. Institutional Coordination and Collaboration 141
4.4.6. Information, Awareness, and Transparency 142
4.4.7. Technology and Data Management 143
4.4.8. The Paradox of Regional Political Instability 144
4.5. Conclusion 144
4.5.1. Limitations 146
REFRENCES 146
CHAPTER 5 152
5. ASSESSING LIVELIHOOD VULNERABILITY OF PERI-URBAN FARMERS TO URBAN EXPANSION AND CLIMATE VARIABILITY IN BAHIR DAR, ETHIOPIA 152
Abstract 153
5.1. Introduction 154
5.2. Methods and materials 156
5.2.1. Description of the study area 156
5.2.2. Research design and methodology 159
5.2.3. Data Sources and Collection Tools 159
5.2.4. Sampling Design and Procedure 160

5.2.5. Methods of Data Analysis 162
5.3. Results and Discussion 169
5.3.1. Exposure to Climate Variability and Hazards 172
5.3.2. Sensitivity to Livelihood Stressors 173
5.3.3. Adaptive Capacity (An Imbalance of Livelihood Capitals) 175
5.3.4. LVI-IPCC Estimate (Interplay of Exposure, Sensitivity, and Adaptive Capacity) 178
5.4. Conclusion 184
REFRENCES 185
CHAPTER 6 191
6. SYNTHESIS 191
The Urban Expansion, Climate Governance, and Livelihood Nexus: An Integrative Synthesis of Bahir Dar's Socio-Ecological Vulnerability 191
6.1. The Need for an Integrated "Nexus" Approach in Regional Cities 191
6.2. The Causal-Chain Framework 192
6.3. Systemic Themes of the Nexus 194
6.3.1. The "Hollow Core" of Spatial Regulation and Microclimatic Warming 194
6.3.2. The "Financial Paralysis Trap" and the fragile of Adaptive Capacity 195
6.3.3. Inconsistent Political Will and the Decline of Social Safety Nets 196
6.4. Contributions to Knowledge 197
CHAPTER 7 199
7. CONCLUSION AND RECOMMENDATION 199
7.1. Conclusion 199
7.2. Recommendations 200
7.2.1. Recommendations for Policy and Practice 200
7.2.2. Recommendations for Future Study 202
Appendixes 203

LIST OF TABLES

Table 2.1 Satellite data and bands for LULC and LST analysis 33
Table 2.2 LULC change categories and their descriptions 34
Table 2.3 LULC distributions and corresponding areas 41
Table 2.4 Summary of overall LST & LST across LU classes in Bahir Dar city (1984-2024) 45
Table 2.5 Mean land surface temperature changes before and after 1994 (°C) 47
Table 2.6 Summary of LU indices in Bahir Dar city for the years 1984, 1994, 2004, 2014 and 2024 49
Table 3.1 Cronbach Alpha (α) Value of Indicators 79
Table 3.2 Accountability Sub-Indicators and RII Values 80
Table 3.3 Participation Sub-Indicators and RII Values. 82
Table 3.4 Equity Sub-Indicators and RII Values 85
Table 3.5 Awareness-Raising Sub-Indicators and RII Values 87
Table 3.6 Institutional Capacity Sub-Indicators and RII Values 89
Table 3.7 Adaptability Sub-Indicators and RII Values 91
Table 3.8 Climate Change Law and Enforcement Sub-Indicators and RII Values 94
Table 3.9 ANOVA Results for UCG Dimensions by Administrative Level 96
Table 3.10 Bahir Dar City UCG Effectiveness Index 97
Table 3.11 Synthesis of UCG Effectiveness and Key Evidence 99
Table 4.1 Definition of Latent Constructs and their Corresponding Indicator Items 123
Table 4.2 Kaiser-Meyer-Olkin Measure and Bartlett's Test results 126
Table 4.3 Rotated Component Matrix of Institutional Constraints to UCG 128
Table 4.4 Goodness-of-Fit Indices for the CFA Measurement Model 130
Table 4.5 Assessment of Construct Reliability and Validity 132
Table 4.6 Goodness-of-Fit Indices for the Structural Model 132
Table 4.7 Results of Hypothesis Testing for the Structural Model 133
Table 5.1 Major components and sub-components for the LVI analysis 164
Table 5.2 Cronbach's Alpha Reliability Coefficients for LVI Major Components 169
Table 5.3 LVI Scores for Major Components and Sub-Indicators across Kebeles 170
Table 5.4 LVI-IPCC Composite Vulnerability Scores by Kebele 179

LIST OF FIGURES

Figure 1.1 Conceptual framework of the study 17
Figure 2.1 Map of the study area 32
Figure 2.2 Methodological flow chart of the study 35
Figure 2.3 LULC maps for the years 1984, 1994, 2004, 2014, and 2024 of Bahir Dar city ... 40
Figure 2.4 LST maps for the years 1984, 1994, 2004, 2014 and 2024 of Bahir Dar city 43
Figure 2.5 LST across land use classes in Bahir Dar city (1984–2024) 46
Figure 2.6 NDVI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024 48
Figure 2.7 NDBI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024 50
Figure 2.8 MNDWI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024 51
Figure 2.9 Correlations between LST and land use indices 52
Figure 3.1 Theoretical Framework of the objective 70
Figure 3.2 Study area map 71
Figure 3.3 Flow Chart of the study 72
Figure 4.0.1 Study area map 118
Figure 4.0.2 The CFA Measurement Model with Standardized Estimates 130
Figure 4.0.3 The Final Structural Equation Model of Institutional Constraints on UCGE ... 135
Figure 5.1 Spatial dynamics of urban expansion in the study area (1984-2024) 157
Figure 5.2 Mean Monthly Rainfall and Temperatures of Bahir Dar from 1984 – 2022 158
Figure 5.3 Livelihood vulnerability based on the nine major components of the LVI 171
Figure 5.4 Indexed Scores for Exposure Sub-Indicators by Kebele 172
Figure 5.5 Indexed Scores for Sensitivity Sub-Indicators by Kebele 174
Figure 5.6 Livelihood Capital Asset Pentagon for Peri-Urban Kebeles in Bahir Dar 176
Figure 5.7 Comparison of the three contributing vulnerability factors (Exposure, Sensitivity, and Adaptive Capacity) across the four sampled kebeles 180
Figure 5.8 LVI-IPCC Composite Vulnerability Scores by Kebele 181
Figure 5.9 Vulnerability by Exposure, Sensitivity, and Adaptive Capacity by Kebele 183
Figure 5.10 Conceptual Flow for assessing Livelihood Vulnerability 184
Figure 6.1 The Integrated Socio-Ecological Causal-Chain of Urban Climate Vulnerability 192

ABBREVIATIONS/ACRONYMS

ANRS	Amhara National Regional State
AVE	Average Variance Extracted
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CR	Composite Reliability
CRGE	Climate-Resilient Green Economy
CSA	Central Statistical Agency
CSO	Civil Society Organization
EFA	Exploratory Factor Analysis
ETM+	Enhanced Thematic Mapper Plus
FBA	Financing and Budget Allocation
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussions
GIS	Geographic Information System
HIC	Human Resources and Institutional Capacity
ICC	Institutional Coordination and Collaboration
IPA	Information and Public Awareness
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interviews
KMO	Kaiser-Meyer-Olkin
LSE	Land Surface Emissivity
LST	Land Surface Temperature
LULC	Land Use/Land Cover
LVI	Livelihood Vulnerability Index
LVI-IPCC	Livelihood Vulnerability Index (using IPCC Framework)
MaxR	Maximum Reliability
MIR	Middle Infrared
MNDWI	Modified Normalized Difference Water Index
MSV	Maximum Shared Variance
NAP-ETH	National Adaptation Plan of Ethiopia
NDC	Nationally Determined Contribution
NDBI	Normalized Difference Built-up Index

NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NIR	Near-Infrared
NMA	National Meteorological Agency
OLI	Operational Land Imager
PCA	Principal Component Analysis
PRF	Policies and Regulatory Frameworks
PWC	Political Will and Commitment
RII	Relative Importance Index
RMSEA	Root Mean Square Error of Approximation
RPI	Regional Political Instability
SDG	Sustainable Development Goal
SEM	Structural Equation Modeling
SLF	Sustainable Livelihoods Framework
SVA	Social Vulnerability to climate change/variability in Africa
SWIR	Shortwave Infrared
TIRS	Thermal Infrared Sensor
TLI	Tucker-Lewis Index
TM	Thematic Mapper
TOA	Top of Atmosphere
UCG	Urban Climate Governance
UCGE	Urban Climate Governance Effectiveness
UGI	Urban Governance Index
UHI	Urban Heat Island
UNECA	United Nations Economic Commission for Africa
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

ABSTRACT

Rapid urbanization and climate change are converging challenges in the Global South, creating a complex nexus of environmental stress, institutional failure, and human vulnerability. In emerging regional capitals like Bahir Dar, Ethiopia, this dynamic is particularly acute, yet a comprehensive understanding of the linkages between the city's physical transformation, the capacity of its governance systems, and the impacts on frontline communities is critically lacking. This study, therefore, conducted a multi-dimensional, integrated analysis of the interplay between urban expansion, climate governance, and the livelihood vulnerability of peri-urban communities in Bahir Dar. The study employed a convergent mixed-methods design, integrating remote sensing and geospatial analysis, the development of composite Relative Importance Indices (RII) from expert surveys, one-way ANOVA to test for perceptual gaps, Structural Equation Modeling (SEM), and the Livelihood Vulnerability Index (LVI) framework. The findings reveal a clear and damaging causal chain. First, the analysis of a 40-year period (1984-2024) demonstrated that Bahir Dar's designation as a regional capital catalyzed an accelerated urban expansion, leading to a 366% increase in built-up areas. This rapid land use and land cover change, characterized by the significant loss of vegetation and agricultural land, directly resulted in the intensification of the Urban Heat Island effect, with a mean Land Surface Temperature of urbanized zones increasing by 6°C over the 40 year study period (1984-2024). Second, the investigation into the institutional response found the city's Urban Climate Governance (UCG) framework to be demonstrably ineffective, with an overall index score (0.489) falling below the functionality threshold 0.50. The evaluation across seven core governance dimensions revealed a system characterized by a single, fragile strength amidst pervasive weakness. While Accountability (RII=0.639) emerged as the sole dimension to surpass the 0.50 effectiveness threshold, it was an isolated strength. All other dimensions, including Participation, Equity, Institutional Capacity, and Adaptability, were found to be critically weak, with Climate Change Law and Enforcement (RII=0.400) representing the most severe point of failure. The ANOVA specifically validated this structural disconnect by identifying a significant perceptual gap in awareness-raising efforts between regional policymakers and local-level implementers. The subsequent diagnostic analysis confirmed that this overall ineffectiveness is primarily driven by a triad of interconnected institutional constraints; a severe deficit in human and institutional capacity, a weak and poorly enforced policy framework, and a lack of sustained political will and leadership. Consequently, the assessment of the human impact showed that peri-urban farming households are in a state of moderate livelihood vulnerability. This condition is defined by high sensitivity, resulting from their dependence on a shrinking agricultural land base, and severely constrained adaptive capacity, stemming from critical deficits in their physical and financial capital. This vulnerability is not an isolated condition but is actively intensified by the unchecked urban expansion and the systemic governance failures identified in the analyses. Collectively, this study concludes that the unmanaged physical expansion of Bahir Dar, enabled by an impaired governance system, is systematically dismantling the resilience of its peri-urban communities. The study recommends a fundamental shift away from isolated policy interventions towards an integrated approach that combines climate-sensitive land-use planning, targeted institutional strengthening, and robust livelihood support programs to build genuine and equitable urban climate resilience.

Keywords: Institutional Constraints, Land Surface Temperature, Livelihood Vulnerability, Urban Climate Governance, Urban Expansion, Bahir Dar.

CHAPTER 1

1. INTRODUCTION

1.1. Background of the Study

Rapid global megatrends urbanization and climate change are the fundamental challenges in the 21st century. Currently, over half of the world's population lives in urban areas. This figure is projected to reach nearly 70% by 2050 (Leeson, 2018; United Nations, 2019). Consequently, cities have become the epicentres of human activity. This urban transition is particularly pronounced in the Global South, where cities in Africa and Asia are experiencing unparalleled rates of growth. However, this rapid expansion often outpaces the development of effective governance and resilient infrastructure, creating significant environmental and social challenges (Myers, 2021).

Moving to the regional scale, this dynamic is especially acute in Africa, where the urban population is expected to double by 2050 (OECD et al., 2025). Nations across the continent, including Ethiopia, are at the forefront of this transformation. Ethiopia stands out as one of Africa's fastest-urbanizing countries, with an urban growth rate that places immense pressure on its cities and natural resources (Terfa et al., 2019). Simultaneously, the country is recognized as highly vulnerable to the impacts of climate change. Its heavy reliance on rain-fed agriculture, coupled with increasing temperature trends and rainfall variability, heightens its susceptibility to climate-related shocks such as droughts and floods, which have significant implications for food security, economic stability, and human well-being (Daba et al., 2025; Feleke et al., 2025).

At the local landscape level, the intersection of rapid urbanization and climate vulnerability manifests physically through significant changes in the urban landscape. The process of unchecked urban expansion drives fundamental and rapid shifts in Land Use/Land Cover (LULC). As cities sprawl outward, vital natural sinks; such as natural vegetation, peri-urban agricultural land, and wetlands; are aggressively replaced by impervious surfaces like asphalt and concrete (Andualem et al., 2023). This LULC is not merely a spatial transition; it represents a profound degradation of local ecological buffers, altering surface albedo and significantly reducing natural evapotranspiration capabilities.

Consequently, this spatial transformation fundamentally alters the urban thermal environment, leading to the well-documented Urban Heat Island (UHI) effect, where cities experience significantly higher Land Surface Temperatures (LST) than their surrounding rural areas

(Almeida et al., 2021; Shi et al., 2021). The severity of this LULC-induced thermal change has been recently validated in comparable regional contexts within Ethiopia. For instance, research in the neighboring secondary city of Gondar by Mekonnen et al. (2023) demonstrated that rapid urbanization and the subsequent LULC changes are the primary drivers instigating the UHI effect, creating localized warming that intensifies broader macro-climatic changes. This phenomenon not only degrades urban ecosystems but also worsens heat-related health risks and increases energy demand for cooling (Cetin et al., 2024; Mekonnen et al., 2023).

The response to these complex and interconnected challenges falls under the umbrella of Urban Climate Governance (UCG). UCG refers to the system of institutions, policies, actors, and processes through which a city manages its response to climate change (Aylett, 2015; Castán-Broto, 2020; Keenan et al., 2019). Effective governance is vital for building urban resilience, yet in many rapidly growing cities, it is hampered by significant institutional constraints. In secondary cities of the Global South, these constraints are particularly pronounced; unlike capital megacities, regional cities operate under severe 'unfunded mandates' where national policies (like the NAP-ETH) are devolved without corresponding decision-making autonomy or fiscal resources. This institutional mismatch results in fragmented policies, inadequate financial resources, weak coordination among municipal departments, and a lack of sustained political commitment, often preventing the successful implementation of long-term climate adaptation strategies (Göpfert et al., 2019).

When these governance systems fail to effectively regulate spatial growth, the consequences are most acutely felt at the human level, particularly in the peri-urban interface. This transitional zone is where the pressures of urban expansion and climate variability collide, creating a unique and intense set of challenges for local communities (Sahana et al., 2023). Peri-urban farmers face a dual threat; the loss of their agricultural land to urban sprawl and the increasing unpredictability of the climate on which their livelihoods depend. In these peripheral zones, land tenure is often insecure, and state land expropriation practices with delayed or inadequate compensation often displace farmers into precarious, low-return off-farm activities. While these communities possess valuable human capital and social networks, their overall adaptive capacity is heavily constrained by extreme deficits in physical (infrastructure) and financial (credit) capital. This convergence of physical, institutional, and social stressors erodes their resilience and increases their livelihood vulnerability, directly threatening their food security and economic stability (Iddrisu et al., 2025).

It is within this complex context that the present study is situated, focusing on Bahir Dar, the capital of the Amhara National Regional State (ANRS) in north-western Ethiopia. Since its designation as a regional capital in 1994, Bahir Dar has experienced explosive demographic and spatial growth, making it a prime case study for examining the nexus of rapid urbanization, environmental change, and governance. Therefore, this study undertakes on a multi-dimensional investigation into the dynamics of urbanization and its impact on the thermal environment, the effectiveness and constraints of the city's climate governance framework, and the resulting vulnerability of its peri-urban communities.

1.2. Statement of the Problem

Ethiopia stands at a critical moment in its urban development trajectory. As one of Africa's fastest urbanizing nations, its urban population has grown from 9.1% in the 1970s to over 22.7% in 2022, with projections indicating that 42% of the population will reside in urban areas by 2050 (CSA, 2018; Tessema, 2017; World Data Atlas, 2022). This transformation is driven by rural-to-urban migration, economic restructuring, and the expansion of urban infrastructure. Yet, the pace and nature of this urbanization are reshaping the country's socio-ecological systems in ways that are both promising and risky.

The nexus between urbanization and climate variability is particularly pronounced in Ethiopia, where cities are expanding into ecologically sensitive zones while grappling with rising temperatures and variable rainfall patterns (Alzamora & Barros, 2020; IPCC, 2022b). Urban expansion often occurs informally and unregulated, leading to land degradation, loss of biodiversity, and increased vulnerability to climate-induced hazards. These dynamics are compounded by the limited adaptive capacity of local institutions, which struggle to manage the dual pressures of urban growth and climate change (FDRE, 2019; Nhamo et al., 2021).

Over the past few decades, Bahir Dar City has undergone a profound transformation, driven by rapid urban expansion and its designation as the capital of the ANRS in 1994. This transformation has significantly altered the city's LULC patterns, with far-reaching implications for its thermal landscape. The replacement of vegetated and agricultural areas with impervious surfaces has led to a marked increase in LST, intensifying the UHI effect and reshaping the city's microclimate (Balew & Korme, 2020; Mekonnen et al., 2023). These changes are not merely environmental; they intersect with socio-economic and governance dimensions, forming a complex web of challenges that demand integrated analysis and response.

The interplay between LULC change and LST in Bahir Dar is particularly pronounced due to the city's unique geographical setting along the shores of Lake Tana and the Abay River. The encroachment of urban development into wetlands, forests, and agricultural lands has disrupted local ecosystems, reduced biodiversity, and diminished the cooling effects of green and blue spaces (Aboye et al., 2023; Admasu et al., 2020). Informal settlements, which constituted nearly 30% of the city's built-up area (Dadi, 2018), have proliferated in ecologically sensitive zones, further exacerbating environmental degradation. These settlements often emerge without adherence to land use planning or building regulations, leading to fragmented urban growth and increased exposure to climate-related hazards.

Remote sensing studies have demonstrated the utility of indices such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI) in capturing LULC dynamics and their thermal implications (Arulbalaji & Gurugnanam, 2014; Saleem et al., 2024). However, many existing studies in Bahir Dar have overlooked the role of water-related indices, such as the Modified Normalized Difference Water Index (MNDWI), in assessing the thermal buffering capacity of wetlands and water bodies (Mohiuddin & Mund, 2024; Xu, 2008). This omission is particularly critical in a city like Bahir Dar, where the proximity to Lake Tana and its associated wetlands plays a vital role in regulating local temperatures and mitigating UHI effects. The current study addresses this gap by integrating NDVI, NDBI, and MNDWI to provide a comprehensive assessment of LULC-induced thermal changes over a four-decade period, including the often-neglected 2002–2008 interval affected by Landsat 7 ETM+ data striping.

The intensification of LST in Bahir Dar is not an isolated phenomenon but part of a broader pattern observed in rapidly urbanizing cities across the Global South. As highlighted in Getu & Bhat (2024), the thermal impacts of urban expansion are closely linked to governance structures, particularly the capacity of local institutions to implement adaptive planning and climate-sensitive urban design. In Bahir Dar, however, the institutional response to these challenges remains limited. Despite national commitments to climate adaptation, such as those outlined in Ethiopia's National Adaptation Plan (NAP-ETH) (FDRE, 2019), local implementation is hindered by fragmented policies, weak regulatory enforcement, and limited stakeholder engagement (Addis, 2023).

UCG in Bahir Dar is further constrained by institutional inertia and a lack of context-specific frameworks. While global indices such as the UN-Habitat Urban Governance Index (UGI) and

national tools like Assele's (2019), environmental governance index offer valuable benchmarks, they often fail to capture the dynamic and localized nature of climate risks in rapidly urbanizing contexts. These tools typically emphasize formal governance structures while overlooking informal mechanisms, adaptive capacity, and the lived experiences of vulnerable populations. In Bahir Dar, where informal settlements and peri-urban expansion are central to the urbanization process, such omissions limit the utility of conventional governance assessments.

The effectiveness of UCG is also shaped by the city's socio-political evolution. The elevation of Bahir Dar to regional capital status catalyzed a wave of infrastructural investments and population influx, accelerating urban sprawl and placing unprecedented demands on municipal institutions (Bahir Dar City Structural Plan Preparation Project Office, 2020). Yet, the institutional frameworks governing urban development and climate adaptation have not evolved at the same pace. As a result, the city faces a governance deficit that undermines its ability to respond to environmental stressors, manage land use conflicts, and ensure equitable access to services.

This governance gap is particularly detrimental in the context of climate variability, which compounds the risks associated with unplanned urban growth. Ethiopia is already experiencing significant climatic shifts, including rising temperatures and variable rainfall patterns, with projections indicating further intensification under all emission scenarios (Almazroui et al., 2020). In Bahir Dar, these changes manifest in increased flooding, prolonged dry spells, and heightened heat stress, all of which disproportionately affect communities residing in informal and peri-urban areas (Alizadeh, 2023; Getachew & Manjunatha, 2021).

Peri-urban areas, situated at the interface of urban and rural systems, are particularly vulnerable to these converging pressures. As urban expansion consumes agricultural land and fragments rural landscapes, peri-urban farmers face declining landholdings, rising land prices, and increased competition for water and other resources (Gebeyehu et al., 2022; Idris et al., 2020). These non-climatic stressors interact with climate variability to create a complex vulnerability landscape that is poorly understood and inadequately addressed in existing research and policy.

Most vulnerability assessments in Ethiopia have focused on rural households, often using frameworks such as the Livelihood Vulnerability Index (LVI) and its IPCC-adapted variant (Alemayehu et al., 2023b; Mekonen & Berlie, 2021). While these studies provide valuable insights into agroecological disparities and coping mechanisms, they rarely consider the unique

challenges faced by peri-urban communities. The lack of clear policy classifications for peri-urban zones further complicates their inclusion in development planning, leaving them in a liminal space between urban and rural governance regimes (Talema & Nigusie, 2023).

International literature similarly overlooks peri-urban vulnerability. Studies on land-lost farmers in China (Huang et al., 2017), climate risks in Indian urban slums (Pandey et al., 2018), and urban households in Vietnam (Ngu et al., 2023) highlight various dimensions of vulnerability but rarely address the compounded effects of urban expansion and climate variability on peri-urban agricultural livelihoods. This gap is particularly concerning in the Ethiopian context, where peri-urban areas are expanding rapidly and play a critical role in urban food systems, ecological services, and socio-economic resilience.

Crucially, these physical, institutional, and social challenges do not exist in isolation; they are deeply intertwined components of a single, failing socio-ecological system. Rapid, unmanaged urban expansion and its corresponding thermal warming (the physical dimension) are directly enabled by the systemic ineffectiveness of local climate governance (the institutional dimension), which fails to enforce spatial master plans, protect ecological buffers, or build institutional capacity. Because the governance system is paralyzed by structural constraints, it remains incapable of regulating land conversion or providing sustainable adaptation infrastructure. Consequently, this governance failure allows physical spatial changes to cascade directly onto the most exposed populations, systematically stripping peri-urban farmers of their agricultural land base while climate variability simultaneously disrupts their crop cycles (the social-livelihood dimension). This three-dimensional failure creates a self-reinforcing 'vulnerability trap' at the urban-rural interface of Bahir Dar, where physical environmental degradation, institutional inertia, and human livelihood precarity perpetually exacerbate one another.

Therefore, this study is designed to close three distinct gaps. In terms of knowledge, existing literature predominantly focuses either on macro-level climate trends or the unique challenges of the capital city, Addis Ababa, leaving a critical empirical void regarding the nexus of urbanization, micro-climate changes, and livelihood vulnerability in rapidly expanding secondary cities like Bahir Dar. In terms of methodology, prior studies typically assess these phenomena in isolation; this study closes the gap by employing a robust convergent mixed-methods design that integrates spatial analysis (LST/LULC), quantitative inferential modeling (SEM/ANOVA), and livelihood vulnerability indices (LVI-IPCC) into a single analytical

framework. In terms of policy, while Ethiopia has ambitious national climate strategies (e.g., NAP-ETH), there is a profound lack of localized diagnostic tools to identify the specific institutional constraints that prevent these national ambitions from being realized at the municipal and peri-urban levels.

1.3. Objectives of the Study

1.3.1. General Objective

The main objective of this study is to conduct a multi-dimensional analysis of the interplay between urban expansion, urban climate governance, and the livelihood vulnerability of peri-urban communities in Bahir Dar, Ethiopia.

1.3.2. Specific Objectives

To achieve the general objective, the study pursues the following specific objectives

1. To analyze the spatiotemporal dynamics of LULC and LST in Bahir Dar, with a comparative analysis of the pre- and post-capital city status (1984-2024).
2. To evaluate the institutional effectiveness of the UCG framework in Bahir Dar.
3. To identify the institutional constraints hindering effectiveness of UCG in Bahir Dar.
4. To assess the livelihood vulnerability of peri-urban farmers in Bahir Dar to the compounded pressures of urban expansion and climate variability.

1.4. Research Questions

To achieve the objectives of the study, the following research questions were drawn

- What are the spatiotemporal dynamics of LULC and LST in Bahir Dar, particularly concerning its pre- and post-capital city status (1984-2024)?
- How effective is the current institutional framework of UCG in Bahir Dar?
- What are the primary institutional constraints hindering the effectiveness of UCG, and what is their relative statistical impact?
- To what extent are peri-urban farming livelihoods vulnerable to the compounded pressures of urban expansion and climate variability?

1.5. Significance of the Study

The significance of this study lies in its integrated approach to understanding the complex nexus of rapid urbanization, climate governance, and human vulnerability. For academia and the research community, this study provides a replicable, convergent mixed-methods

framework that advances UCG research. It offers a rigorous diagnostic assessment that not only evaluates institutional effectiveness but also statistically identifies the constraints undermining it. Theoretically, the study enriches livelihood vulnerability literature by explicitly conceptualizing vulnerability as a product of compounded stressors, assessing climate variability alongside the non-climatic stressor of urban expansion. Furthermore, it provides a detailed, long-term empirical baseline for environmental and governance dynamics in an emerging secondary regional capital, a context critically under-researched compared to megacities.

For policymakers and practitioners, the study provides a wealth of evidence-based, actionable insights. For municipal and regional planners, the detailed spatial analysis of LULC and LST dynamics offers clear empirical justification for prioritizing green infrastructure, protecting wetlands, and implementing climate-sensitive land-use planning. Additionally, for governance practitioners, the identification of systemic barriers such as human resource deficits, financial constraints, and weak policy enforcement provides a precise roadmap for targeted institutional reform. Ultimately, the study acts as a ground-truthed diagnostic tool that illuminates the local implementation challenges of national climate strategies, such as Ethiopia's NAP-ETH, thereby guiding the design of more effective support programs across Sub-Saharan Africa.

Finally, at the local level, the study holds profound significance for peri-urban communities. By quantifying the acute sensitivity of peri-urban farmers to land loss and climate shocks, the research gives visibility to highly marginalized populations whose traditional coping mechanisms are being overwhelmed. The findings provide the crucial, context-specific data required by local governments, non-governmental organizations (NGOs), and development agencies to design targeted adaptation interventions. These insights can directly inform strategies aimed at securing land tenure, promoting sustainable livelihood diversification, and ultimately building the adaptive capacity of farming communities living at the forefront of urban expansion.

1.6. Scope and Delimitations of the Study

Geographical Scope: This study is geographically focused on Bahir Dar, the capital city of the ANRS in north-western Ethiopia. The city was purposively selected as it represents a critical case study of a rapidly expanding regional capital facing the dual pressures of urbanization and climate variability. The investigation is multi-scalar, examining different geographical units according to the specific objectives of each manuscript. The analysis of

urbanization and its thermal impacts encompasses the entire administrative boundary of the city and its evolving landscape. The investigation into UCG and its constraints focuses on the institutional actors and frameworks at the regional, city, and sub-city levels. Finally, the assessment of livelihood vulnerability narrows the focus to the peri-urban interface, specifically targeting the administrative kebeles that form the transitional zone between the core urban area and the surrounding rural landscape.

Thematic Scope: Thematically, this study is delimited to a multi-dimensional analysis that connects the physical environment, governance systems, and human livelihoods. The study investigates the spatiotemporal dynamics of LULC change and its impact on the urban thermal landscape, quantified through LST and related geospatial indices (NDVI, NDBI, MNDWI). It then assesses the effectiveness of UCG across key principles, including accountability, participation, and equity. This is followed by a diagnostic analysis of the primary institutional constraints that hinder effective governance, such as deficiencies in policy, finance, human resources, and political will. Finally, the study examines the livelihood vulnerability of peri-urban farmers, conceptualized through the integrated lens of the IPCC framework (exposure, sensitivity, adaptive capacity) and the Sustainable Livelihoods Framework (human, social, natural, physical, and financial capitals).

Temporal Scope: The study employs a multi-temporal approach to capture both long-term environmental trends and current governance and livelihood realities. The analysis of LULC and LST dynamics covers a 40-year period from 1984 to 2024. This extended timeframe was deliberately chosen to facilitate a comparative analysis, allowing for a distinct examination of the pre-capital period (1984-1994) and the post-capital period (1994-2024), thereby isolating the impacts of accelerated urbanization. The data for the assessment of UCG and livelihood vulnerability, including surveys, interviews, and focus group discussions, were collected between 2024 and 2025, providing a contemporary snapshot of the institutional and social conditions within the context of the long-term environmental changes.

Methodological Scope: The study is methodologically framed within a convergent mixed-methods approach, integrating quantitative and qualitative techniques to provide a comprehensive and triangulated analysis. The quantitative scope includes geospatial analysis using remote sensing and GIS to assess LULC and LST dynamics; the development of composite indices to measure governance effectiveness and livelihood vulnerability; and advanced statistical modeling, specifically SEM, to identify the causal relationships between

institutional constraints and governance outcomes. The qualitative scope involves thematic analysis of data from key informant interviews (KIIs), focus group discussions (FGDs), and official policy and planning documents to provide the rich contextual understanding needed to interpret the quantitative findings. This approach is delimited to providing a holistic diagnosis rather than focusing on a single methodological tradition.

1.7. Theoretical and Empirical Evidence of the Study

1.7.1. Conceptualizing the Urbanization, Land Use, and Climate Nexus

Urbanization is one of the defining global trends of the 21st century, profoundly reshaping climate patterns and governance structures. As a complex societal shift, it involves not only the migration of populations from rural to urban areas but also a fundamental economic transition and the physical transformation of landscapes (Chen et al., 2014). This process of urban expansion is dynamic; it converts non-urban territories into built environments, replacing natural vegetation and agricultural lands with impervious surfaces (Angel et al., 2005). While this spatial growth drives economic opportunity, it simultaneously alters the Earth's surface energy balance, creating a cascade of environmental consequences including habitat loss, hydrological disruption, and ecosystem fragmentation (Alberti et al., 2003; Seto et al., 2012).

The relationship between this urban expansion and climate dynamics is a complex, recursive interplay. Cities are both drivers of and battlegrounds for climate change (Seto et al., 2014). On one hand, the physical process of urbanization intensifies local climate variability. The replacement of natural land cover with built-up materials increases heat retention, leading to Urban Heat Island (UHI) effect, which exacerbates temperature variations and reinforces the feedback loop between urban growth and climatic stress (Mekonnen et al., 2023). On the other hand, expanding cities are increasingly exposed to climate-induced hazards such as extreme heat waves, variable precipitation, and flooding (Wilby, 2008). This convergence means that urban areas must simultaneously manage their carbon footprint while adapting to an increasingly volatile thermal and hydrological landscape.

This nexus is particularly acute in the Global South, where the pace of urbanization often outstrips the capacity of institutions to manage it. In developing countries, UCG faces profound structural challenges. Unlike their counterparts in the Global North, cities in these regions are often constrained by limited financial resources, inadequate technical capacity, and weak governance structures (Castán-Broto & Westman, 2020; Pasquini, 2020). The implementation of comprehensive climate action is frequently hampered by corruption, a lack of coordination

between government levels, and low public awareness (Solorio, 2021). Consequently, despite the existence of national policy frameworks, local institutional effectiveness remains limited, leaving cities ill-equipped to integrate resilience into long-term urban planning (Addis et al., 2022, 2023).

The consequences of this unmanaged expansion and governance failure are most visibly felt at the peri-urban interface. These transitional zones, where urban and rural systems collide, are characterized by a complex mix of traditional livelihoods and evolving infrastructure (Ricci, 2012). As the frontline of urban sprawl, peri-urban areas witness the direct conversion of agricultural land into built-up environments. Here, communities face a dual threat; the socio-economic pressure of land loss and the physical pressure of climate variability. This convergence creates a unique landscape of vulnerability, where traditional agrarian livelihoods are eroded by shifts in land use and weather patterns (Afriyie et al., 2020), necessitating targeted interventions that recognize the compounded nature of these risks.

1.7.2. Theoretical Frameworks for Governance

To systematically analyze the effectiveness and underlying constraints of UCG in Bahir Dar, this study employs a multi-dimensional theoretical framework rather than relying on a single analytical lens. A central premise of governance theory is that the quality of institutions directly shapes societal outcomes, and in the context of urban climate change, the desired outcome is enhanced climate resilience. To understand how this outcome is achieved or inhibited, the study integrates insights from New Institutionalism, Climate Justice, Collaborative and Polycentric Governance, Adaptive Governance, and Institutional Capacity Theory. Together, these theories provide the rigorous justification for the variables measured in this study, explaining the complex interplay between formal structures, resource capabilities, and the lived reality of governance on the ground.

The foundational understanding of how governance institutions function is drawn from New Institutionalism. This theory posits that governance outcomes are determined by the interaction between formal institutions, such as written laws, regulations, and property rights, and informal institutions, which include unwritten norms, social conventions, and codes of conduct. Together, these constitute the "rules of the game" (North, 1990). In the context of UCG, effective climate action requires not only robust formal rules, such as clear law enforcement and accountability structures, but also the alignment of these rules with the prevailing informal norms of political and social behavior. A divergence between formal mandates and informal

practices often leads to a policy-implementation gap, where regulations exist on paper but lack functional enforcement. However, New Institutionalism alone focuses primarily on efficiency and rule adherence. To address the social dimensions of climate change, this study complements it with Climate Justice Theory, which demands that institutions be not merely effective but also just. This perspective emphasizes that the burdens and benefits of climate action must be distributed fairly, particularly in developing cities where vulnerability is unevenly shared (Furnaro & Kay, 2022). Therefore, equity, ensuring the protection of vulnerable populations and the fair allocation of resources, is positioned in this study as a non-negotiable component of legitimate governance.

Recognizing that climate change is a "wicked problem" that defies simple, top-down solutions, the study also draws heavily on Collaborative and Polycentric Governance theories to assess the dynamics of actor interaction. Effective UCG is inherently polycentric, requiring coordination across multiple, overlapping centers of authority, ranging from national ministries and regional bureaus to municipal agencies, private sector actors, and community groups (Jordan, 2018). The effectiveness of this complex web hinges on the principles of collaborative governance, which emphasizes the active involvement of all stakeholders in decision-making (Nabatchi & Emerson, 2023). This theoretical strand justifies the study's focus on participation and awareness-raising, positing that fragmented or siloed governance structures inevitably lead to inaction. Without meaningful collaboration, the governance system fails to leverage local knowledge or build the broad-based consensus necessary for long-term climate resilience.

To diagnose the system's ability to endure and evolve over time, the study integrates Adaptive Governance with Institutional Capacity Theory. Adaptive Governance provides the normative ideal for resilience, suggesting that a governance system must be able to learn, respond to new information, and manage uncertainty through flexible, experimental institutions (Chaffin et al., 2014; Folke, Hahn, Olsson, et al., 2005). This requires the development of adaptive rules and structures designed for flexibility rather than bureaucratic rigidity. However, a system cannot become adaptive without a foundational set of resources. This is where Institutional Capacity Theory serves as the primary diagnostic lens for the study. It posits that the effectiveness of governance is fundamentally determined by the collective abilities, resources, and structural arrangements of its institutions to perform functions, solve complex problems, and achieve objectives (World Bank, 2011).

In this study, strong institutional capacity is conceptualized as a necessary precondition for adaptive governance. This capacity is operationalized through several critical dimensions that inform the analysis of constraints. Human and technical capacity refers to the availability of skilled personnel, technical expertise, and relevant data required to design, implement, and monitor climate policies, where a deficit can lead to poorly designed interventions (UNDP, 2011). Financial capacity involves the ability to mobilize, allocate, and manage sufficient and sustainable financial resources.

Furthermore, political capacity centers on the political will, leadership commitment, and stability required to prioritize climate change on the policy agenda. Structural capacity pertains to the existence of clear policies and well-defined mandates. By synthesizing these theories, the study establishes a comprehensive framework where Institutional Capacity acts as the necessary input, New Institutionalism and Collaborative Governance describe the structural and relational processes, and Adaptive Governance describes the desired outcome of resilience. This integrated perspective allows for a granular diagnosis of not just whether the governance system in Bahir Dar is failing, but specifically why it is failing to meet the challenges of rapid urbanization.

1.7.3. Theoretical Perspectives of Livelihood Vulnerability

The concept of vulnerability within climate change and development discourse is characterized by a diversity of definitions and methodological approaches, leading to what some scholars describe as conceptual confusion. Fundamentally, vulnerability is understood as the extent to which a system is susceptible to, or unable to cope with, the adverse impacts of stressors, encompassing climate variability and extremes (IPCC, 2001). However, the specific conceptualization of this term varies significantly based on disciplinary focus. Kelly and Adger (2000) assert that these varying conceptualizations have profound implications for assessment methodologies, levels of certainty, and policy relevance. Consequently, vulnerability analysis has traditionally bifurcated into two distinct streams: the biophysical approach and the socioeconomic approach.

The biophysical approach focuses primarily on assessing the physical impacts of environmental stressors on social and biological systems. As noted by Deressa et al. (2008), this approach examines factors such as hazards, exposure levels, and the physical losses resulting from specific hazardous events. It perceives vulnerability largely as an outcome of climate change often termed "end-point vulnerability." While useful for mapping hazards, this approach tends

to emphasize physical impacts while potentially overlooking the broader social and economic contexts that shape a community's ability to respond. In contrast, the socioeconomic approach emphasizes the political and social circumstances of individuals or groups (Füssel, 2007). Here, vulnerability is viewed as a socially and economically constructed phenomenon, influenced by factors such as education, gender, wealth, health status, and political power. While this provides valuable insights into societal determinants, it may conversely overlook critical environmental factors and resource availability.

To bridge this dichotomy, this study adopts the integrated assessment approach, which combines elements from both biophysical and socioeconomic perspectives to provide a comprehensive understanding of livelihood vulnerability (Füssel & Klein, 2006; O'Brien et al., 2007). This approach acknowledges the mutual interactions between humans and their environment. It operationalizes the definition provided in the Fourth Assessment Report of the IPCC (2007), which defines vulnerability as a function of three core components i.e. exposure, sensitivity, and adaptive capacity. The most recent IPCC assessment (IPCC, 2022c) further broadens this, highlighting vulnerability as the inclination or predisposition to harm.

In this integrated framework, Exposure represents the external side of vulnerability, referring to the magnitude and duration of climate-related stressors such as rainfall variability or temperature extremes. Sensitivity refers to the degree to which a system is affected, either adversely or beneficially, by these exposures. Finally, Adaptive Capacity refers to the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. As Ofgeha (2021) distinguishes, exposure is often an external attribute, whereas sensitivity and adaptive capacity are internal attributes shaped by socioeconomic factors. By integrating these dimensions, this approach offers a holistic tool for analyzing peri-urban vulnerability, a perspective advocated by the United Nations Framework Convention on Climate Change for its applicability at national and local levels in Africa (Nguyen et al., 2016).

1.7.3.1. The Sustainable Livelihoods Framework

To operationalize the "Adaptive Capacity" component of the vulnerability framework, this study utilizes the Sustainable Livelihoods Framework (SLF). Livelihoods encompass the diverse capabilities, assets, and activities required to secure the necessities of life (Chambers & Conway, 1991). The primary benefit of utilizing the SLF in this study is its ability to move beyond generic, macro-level vulnerability metrics. By unpacking 'Adaptive Capacity' into a

multi-dimensional index based on five core livelihood capitals, the SLF provides a structured, quantitative diagnostic tool to analyze how peri-urban households navigate the "internal" dimensions of vulnerability (Ofgeha, 2021). It posits that a household's ability to cope with stressors, whether they are climate anomalies or the pressures of urban expansion, depends entirely on their access to a balanced portfolio of these five assets.

In this study, Natural Capital is operationalized as the vital agricultural land holdings and potable water sources of Bahir Dar's peri-urban farmers. Under the pressure of rapid urban sprawl, this capital is the most compromised asset, as horizontal city expansion directly encroaches on peripheral agricultural areas, reducing farm sizes and stripping households of their primary productive resource (Ricci, 2012).

In the context of Bahir Dar's transitional kebeles (such as Zenzelma and Woramit), Physical Capital refers to the critical deficits in basic infrastructure and modern technology. Specifically, this study measures deficits in household electricity, access to all-weather roads, and agricultural inputs like modern irrigation systems and improved seeds, which severely restrict the physical capacity of farmers to adapt to climatic shifts.

Here, Human Capital is represented by the internal capacities of the household, specifically the years of traditional farming experience, the dependency ratio, and the formal educational levels of the household heads in the study area, which serve as essential cognitive resources for navigating changing climatic and economic conditions (Wisner et al., 2014).

For Bahir Dar's peri-urban households, Financial Capital denotes their highly constrained financial health, characterized by extreme income dependency on rain-fed farming, a critical lack of income diversification, and systemic institutional barriers in accessing formal government credit or micro-savings services (Yeneneh et al., 2024).

Finally, Social Capital in this study is anchored in the robust, informal safety nets of the community. It is measured through active membership in Community-Based Organizations (CBOs) and deep-seated, traditional mutual-aid and labor-sharing practices (such as Debo and Wenfel), which serve as the primary defensive buffers for households during sudden climate or land-expropriation crises.

This framework allows for a highly contextualized analysis of the "internal" vulnerability of peri-urban farmers in Bahir Dar. By mapping these five assets, the SLF helps explain why

households exposed to the same level of external climate stress or urban encroachment experience vastly different levels of impact. It highlights that vulnerability is not just about the external shock, but about the fragility of the specific, highly unequal asset portfolio required to withstand it.

1.7.4. Conceptual Framework

To systematically analyze the interaction between these three domains (urban expansion, the functionality of UCG, and livelihood vulnerability) comprehensive conceptual framework was developed based on a causal-chain logic. This framework integrates the concept of urban expansion as a primary driver of change, the mediating role of the urban governance system in managing these changes, and the resulting impacts on the livelihood security of frontline communities. It suggests that the socio-economic drivers of population growth, rural-urban migration, and economic development act as the initial catalysts, fueling a central process of rapid urbanization and physical expansion. This expansion, in the context of Bahir Dar, is not merely a demographic shift but a spatial transformation that generates two distinct but interrelated streams of impact i.e. environmental stress and socio-economic displacement.

The first pathway in the framework outlines the environmental impacts of this expansion. It suggests that the physical sprawl of the city directly alters the landscape through LULC changes, specifically the loss of vegetation and the proliferation of impervious surfaces. This physical transformation leads to measurable environmental stresses, most notably the intensification of the UHI effect and rising LST. Simultaneously, the second pathway outlines the socio-economic impacts, where the physical expansion of the city encroaches upon peri-urban agricultural land. This process results in the loss of natural capital for farmers and necessitates a forced livelihood change from agricultural to non-agricultural activities, often without adequate preparation or support.

The framework identifies UCG as the critical mediating system situated between these impacts and the final human outcome. Theoretically, this system of institutions, policies, and actors is responsible for regulating urban growth, mitigating environmental stress, and supporting livelihood transitions. However, the framework imagines that this mediating role is fundamentally characterized by failure. It suggests that the UCG system in Bahir Dar is undermined by a specific set of institutional constraints, such as deficits in human capacity, weak policy enforcement, and a lack of political will. Consequently, instead of acting as a

buffer that reduces risk, the governance system acts as a porous filter, allowing the negative environmental and socio-economic impacts to pass through unchecked.

The final component of the framework is livelihood vulnerability, which represents the cumulative outcome where all preceding physical and institutional factors converge. The conceptual framework explicitly integrates the SLF into its causal-chain logic by operationalizing 'Adaptive Capacity' as an asset pentagon of the five household capitals (Natural, Physical, Human, Financial, and Social). As schematically illustrated in Figure 1.1, these five capitals represent the internal, domestic buffer of the peri-urban households. The framework suggests that the physical and institutional shocks (unmanaged LULCC and failing UCG systems) do not strike a neutral target; instead, they directly attack and erode this asset base. Specifically, urban expansion depletes Natural Capital (loss of farmland), while the failure of the governance system fails to replenish Physical Capital (inadequate infrastructure) or Financial Capital (credit constraints), thereby forcing households to rely almost exclusively on their Human and Social Capital (Debo and Wenfel) to survive. Ultimately, the LVI-IPCC composite index is calculated by using this SLF asset pentagon as the direct determinant of Adaptive Capacity, illustrating how a skewed and degraded asset portfolio directly drives the overall livelihood vulnerability score (-1 to +1) (Figure 1.1).

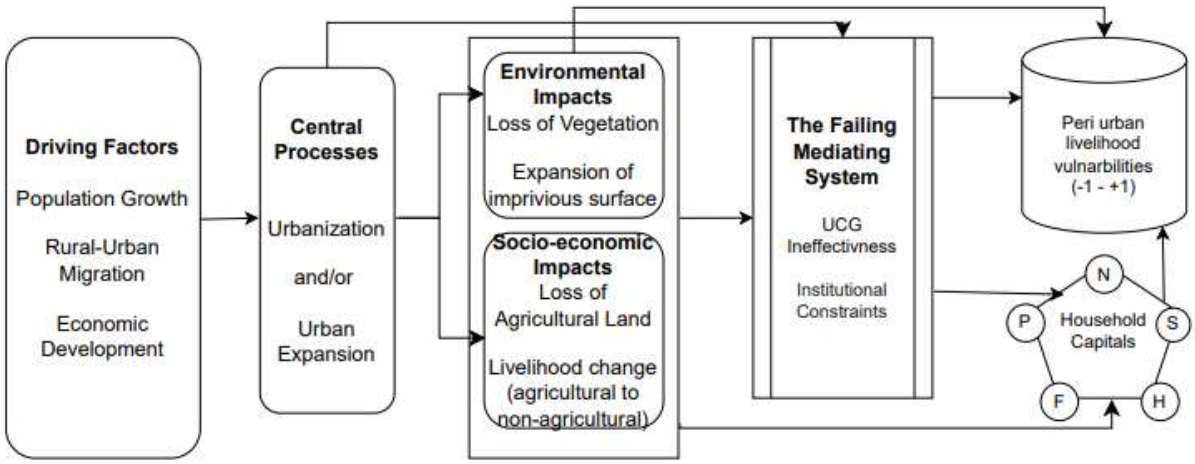


Figure 1.1 Conceptual framework of the study

Note: *N=natural capital, S=social Capital, H=human capital, F=financial capital, P=physical capital (Source: Modified from Belete, 2022)*

1.8. Philosophical Foundation of the Study

The research paradigm and philosophy form the intellectual foundation of any study. This foundation is crucial as it represents the researcher's core beliefs about the nature of reality (ontology) and determines how legitimate knowledge is acquired (epistemology). For this

work, making this philosophical stance explicit is crucial for establishing the rigor and coherence of the research design and for justifying the choice of methodology. Given the complex, multi-dimensional nature of the urban-climate nexus in Bahir Dar, a problem involving measurable physical changes, abstract institutional failures, and nuanced human experiences, this study is grounded in a pragmatist research philosophy. Pragmatism was selected as the overarching lens because it moves beyond the traditional intellectual tensions between objectivist and subjectivist worldviews, adopting a problem-centered approach that prioritizes 'what works' to generate actionable insights and solutions (Goldkuhl, 2011).

This practical necessity guides the methodological pluralism of the study, which integrates two distinct epistemological positions. The first is a modified Post-Positivism, which provides the structured framework for quantitative inquiry into observable, external phenomena. This is essential for Objective 1, guiding the geospatial analysis and quantification of the physical environmental problem, namely LULC changes and LST dynamics (Shanks, 2002). It is also applied to the quantitative components of Objectives 2, 3, and 4, which involve the systematic measurement of governance dimensions (using Likert-scale surveys) and the construction of vulnerability indices. This systematic examination is necessary to establish the empirical magnitude of the problem and the statistical significance of hypothesized relationships, such as the constraints on governance effectiveness.

Conversely, the study simultaneously employs Interpretivism/Constructivism to address the deeper, contextual, and process-oriented questions. This stance acknowledges that social realities, such as institutional effectiveness, political commitment, and livelihood vulnerability, are complex constructs deeply influenced by human perceptions and local social dynamics (Levers, 2013). This perspective is critical for Objective 2 and 3, as KIIs are used to contextualize and explain why the numerically scored governance dimensions may be failing, exposing the informal constraints and power dynamics not captured by the quantitative one. It is equally vital for Objective 4, where FGDs provide the rich, lived experiences necessary to interpret the final livelihood vulnerability index, ensuring the study captures the mechanisms that intensify vulnerability among peri-urban farmers.

The final strength of the pragmatic approach lies in the way it enables the triangulation and integration of these divergent findings. By drawing on both empirical evidence (Post-Positivism) and contextual understanding (Interpretivism), the study moves beyond a fragmented, sector-specific view of the problem. This ensures that the study generates

knowledge that is not only statistically sound but also deeply relevant and actionable for informing evidence-based policy aimed at building resilient urban systems in Bahir Dar.

1.8.1. Research Approach and Design

The multi-dimensional nature of the study demanded a holistic investigation that neither purely positivist nor purely interpretivist methods could achieve alone. Consequently, this study employs a Mixed-Methods approach as its core strategy. This methodology is good for integrating quantitative metrics with qualitative contextual depth, allowing the study to transcend the inherent limitations of mono-method studies (Howe & McKay, 2007; Poth, 2018). The approach is not merely a combination of techniques, but a deliberate strategy to achieve a fuller, and stronger understanding of the system under investigation.

The overall study is framed by a Convergent Mixed-Methods Design. This design was chosen to ensure the holistic understanding required by the integrated research problem. This design involved the simultaneous collection of diverse quantitative and qualitative data streams drawn from the four research objectives (Creswell, 2009; Poth, 2018). The quantitative strand was essential for objectively measuring the scale and magnitude of the problem. This involved two major techniques. First, Geospatial Analysis was employed for Objective 1 (LULC and LST dynamics), using remote sensing and GIS to quantify environmental trends over a 40-year period (1984-2024), providing an empirical baseline of the physical changes in Bahir Dar.
Second, Survey-Based Metrics and advanced statistical techniques were utilized for Objectives 2, 3, and 4 to systematically measure abstract concepts. This included the use of the Relative Importance Index (RII) to measure UCG effectiveness and the LVI-IPCC composite index to quantify Livelihood Vulnerability. Furthermore, SEM was employed in Objective 3 to rigorously test causal relationships, identifying the statistical significance and hierarchy of the institutional constraints that undermine governance.
The integration of the quantitative and qualitative data strands occurred during the interpretation stage, where statistical results were systematically cross-examined against thematic qualitative narratives. This methodological strategy facilitates triangulation, enhancing the credibility of the findings by validating quantitative scores with rich qualitative narratives. It ensures that the overall conclusion is a strong, well-rounded statement reflecting both the statistically significant facts and the socio-contextual mechanisms that drive them in Bahir Dar.

1.9. Organization of the Dissertation

This dissertation is organized into seven chapters, supplemented with a consolidated list of references and appendices. To provide a clear and comprehensive understanding of the study, a brief description of each chapter and its respective content is presented below.

Chapter one presents a general overview of the dissertation. It includes the background of the study, the statement of the problem, the research objectives and questions, the significance, and the scope and delimitations of the study. It also establishes the foundational conceptual theories and the overall research methodology.

Chapter two is titled "Urbanization and Land Surface Temperature Dynamics in Bahir Dar, Ethiopia: A Comparative Analysis of Pre- and Post-Capital Status." This chapter empirically establishes the physical environmental problem by analyzing the spatiotemporal dynamics of LULC and LST over a 40-year period (1984-2024). It provides a comparative analysis of these trends before and after Bahir Dar's designation as a regional capital.

Chapter three is titled "Evaluating Institutional Effectiveness in Urban Climate Governance: The Case of Bahir Dar City, Northwestern Ethiopia." This chapter diagnoses of the governance system by providing a comprehensive assessment of the effectiveness of UCG in Bahir Dar. It evaluates the performance of the governance framework across seven key dimensions to determine its overall capacity to build climate resilience.

Chapter four is titled "Institutional Constraints to Effective Urban Climate Governance: A Case Study of Bahir Dar City, Ethiopia." Building on the previous chapter, this study delves deeper to identify the specific institutional constraints that hinder effective climate action. It identifies significant barriers and determines their hierarchical influence, identifying critical bottlenecks such as human resource capacity and policy deficiencies.

Chapter five is titled "Assessing Livelihood Vulnerability of Peri-Urban Farmers to Urban Expansion and Climate Variability in Bahir Dar, Ethiopia." This chapter assesses the human consequences of the interacting environmental and governance challenges. It employs the LVI framework to analyze the vulnerability of peri-urban farming communities to the compounded pressures of urban expansion and climate variability.

Chapter Six deals with the Synthesis. This section integrates the key findings from the preceding four chapters, highlighting their interrelations, demonstrating the overarching causal chain, and presenting the theoretical implications of the integrated results. Chapter Seven deals

with the Conclusion and Recommendations. This final chapter summarizes the main findings in response to the research questions and provides targeted, evidence-based recommendations for policymakers, urban planners, and future researchers.

REFRENCES

Aboye, B. H., Gebre-Egziabher, T., Kebede, B., & Minale, A. S. (2023). Changing farming practices as integral to sustenance and cropland-use loss in the context of urban expansion: The case of Jimma City, Southwest Ethiopia. *Cleaner Environmental Systems*, *9*, 100117. https://doi.org/10.1016/J.CESYS.2023.100117

Addis, T. L. (2023). Climate Change Governance in Addis Ababa City Administration, Ethiopia. In *Dissertation*. Addis Ababa University.

Addis, T. L., Birhanu, B. S., & Italemahu, T. Z. (2022). Effectiveness of Urban Climate Change Governance in Addis Ababa City, Ethiopia. *Urban Science*, *6*(3). https://doi.org/10.3390/urbansci6030064

Addis, T. L., Birhanu, B. S., & Italemahu, T. Z. (2023). Factors Affecting Climate Change Governance in Addis Ababa City, Ethiopia. *Sustainability (Switzerland)*, *15*(4). https://doi.org/10.3390/su15043235

Admasu, W. F., Boerema, A., Nyssen, J., Minale, A. S., Tsegaye, E. A., & Passel, S. Van. (2020). Uncovering ecosystem services of expropriated land: The case of urban expansion in bahir dar, northwest ethiopia. *Land*, *9*(10), 1–20. https://doi.org/10.3390/land9100395

Afriyie, K., Abass, K., & Adjei, P. O. W. (2020). Urban sprawl and agricultural livelihood response in peri-urban Ghana. *International Journal of Urban Sustainable Development*, *12*(2), 202–218. https://doi.org/10.1080/19463138.2019.1691560

Alberti, M., Marzluff, J. M., Shulenberger, E., Bradley, G., Ryan, C., & Zumbrunnen, C. (2003). Integrating humans into ecology: Opportunities and challenges for studying urban ecosystems. *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, *53*(12), 143–158. https://doi.org/10.1007/978-0-387-73412-5_9

Alemayehu, Z. Y., Minale, A. S., & Legesse, S. A. (2023). Vulnerability of local farmers' livelihood to climate variability across different agro ecology zone in Suha watershed, Upper Blue Nile basin, Ethiopia. *Climate and Development*, *16*(1), 36–53. https://doi.org/10.1080/17565529.2023.2178253

Alizadeh, O. (2023). Changes in the mean and variability of temperature and precipitation over global land areas. *Environmental Research: Climate*, *2*(3), 035006. https://doi.org/10.1088/2752-5295/ACE279

Almazroui, M., Saeed, F., Saeed, S., Nazrul Islam, M., Ismail, M., Klutse, N. A. B., & Siddiqui, M. H. (2020). Projected Change in Temperature and Precipitation Over Africa from CMIP6. *Earth Systems and Environment*, *4*(3), 455–475. https://doi.org/10.1007/S41748-020-00161-X/FIGURES/14

Alzamora, B. R., & Barros, R. T. de V. (2020). Review of municipal waste management charging methods in different countries. *Waste Management*, *115*, 47–55.

https://doi.org/10.1016/J.WASMAN.2020.07.020

Andualem, T. G., Peters, S., Hewa, G. A., Boland, J., & Myers, B. R. (2023). Spatiotemporal trends of urban-induced land use and land cover change and implications on catchment surface imperviousness. *Applied Water Science*, *13*(12), 1–16. https://doi.org/10.1007/S13201-023-02029-7/FIGURES/8

Angel, S., Sheppard, S. C., & Civco, D. (2005). *The Dynamics of Global Urban Expansion. Transport and Urban Development Department*. https://www.researchgate.net/publication/260317174

Arulbalaji, P., & Gurugnanam, B. (2014). Evaluating the normalized difference vegetation index using landsat data by ENVI in salem district, Tamilnadu, India. *International Journal of Development Research*, *4*(9), 1844–1846.

Assele, A. A. (2019). The Political Economy of Environmental Governance in Ethiopia: Exploring Trends, Actors and Drivers. In *Dissertation* (Issue April). Addis Ababa University.

Aylett, A. (2015). Institutionalizing the urban governance of climate change adaptation: Results of an international survey. *Urban Climate*, *14*, 4–16. https://doi.org/10.1016/J.UCLIM.2015.06.005

Bahir Dar City Structural Plan Preparation Project Office. (2020). *Population Study Report*.

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

Castán-Broto, V. (2020). Climate change politics and the urban contexts of messy governmentalities. *Territory, Politics, Governance*, *8*(2), 241–258. https://doi.org/10.1080/21622671.2019.1632220;WGROUP:STRING:PUBLICATION

Castán-Broto, V., & Westman, L. K. (2020). Ten years after Copenhagen: Reimagining climate change governance in urban areas. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(4), e643. https://doi.org/10.1002/WCC.643

Cetin, M., Ozenen Kavlak, M., Senyel Kurkcuoglu, M. A., Bilge Ozturk, G., Cabuk, S. N., & Cabuk, A. (2024). Determination of land surface temperature and urban heat island effects with remote sensing capabilities: the case of Kayseri, Türkiye. *Natural Hazards*, *120*(6), 5509–5536. https://doi.org/10.1007/S11069-024-06431-5/METRICS

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society, Published Online: Sep 30, 2014 | Doi:10.5751/ES-06824-190356*, *19*(3). https://doi.org/10.5751/ES-06824-190356

Chambers, R., & Conway, G. (1991). To the hands of the poor: water and trees. *To the Hands of the Poor: Water and Trees*.

Chen, M., Zhang, H., Liu, W., & Zhang, W. (2014). The Global Pattern of Urbanization and Economic Growth: Evidence from the Last Three Decades. *PLOS ONE*, *9*(8), e103799. https://doi.org/10.1371/JOURNAL.PONE.0103799

Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches. In *SAGE Publications Asia-Pacific Pte. Ltd* (Third, Vol. 4, Issue 11). SAGE

Publications Ltd. https://doi.org/10.1128/microbe.4.485.1

CSA. (2018). Statistical report on the 2018 urban Employment Unemployment survey. *Central Statistical Agency, Ethiopia, October*, 301.

Daba, B., Regasa, T., & Mammo, S. (2025). Impacts of climate change and variability on rural livelihoods and adaptation strategies in Ethiopia: a review paper. *Frontiers in Climate*, *7*, 1563176. https://doi.org/10.3389/FCLIM.2025.1563176/BIBTEX

Dadi, T. T. (2018). *The influence of land management on the prevalence of informal settlement and its implication for environmental management in Bahir Dar city, Ethiopia*. University of South Africa.

de Almeida, C. R., Teodoro, A. C., & Gonçalves, A. (2021). Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review. *Environments 2021, Vol. 8, Page 105*, *8*(10), 105. https://doi.org/10.3390/ENVIRONMENTS8100105

Deressa, T., Hassan, R. M., & Ringler, C. (2008). Measuring Ethiopian farmers' vulnerability to climate change across regional states. *IFPRI Discussion Paper*, *806*(October), 32. http://www.ifpri.org/publication/measuring-ethiopian-farmers-vulnerability-climate-change-across-regional-states%5Cnhttp://www.ifpri.org/sites/default/files/publications/ifpridp00806.pdf

FDRE. (2019). *Ethiopia's Climate Resilient Green Economy Strategy. National Adaptation Plan* (Issue May).

Feleke, H. G., Amdie, T. A., Rasche, F., Mersha, S. Y., & Brandt, C. (2025). Climate on the Edge: Impacts and Adaptation in Ethiopia's Agriculture. *Sustainability 2025, Vol. 17, Page 5119*, *17*(11), 5119. https://doi.org/10.3390/SU17115119

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*(Volume 30, 2005), 441–473. https://doi.org/10.1146/ANNUREV.ENERGY.30.050504.144511/CITE/REFWORKS

Furnaro, A., & Kay, K. (2022). Labor resistance and municipal power: Scalar mismatch in the Los Angeles Green New Deal. *Political Geography*, *98*, 102684. https://doi.org/10.1016/J.POLGEO.2022.102684

Füssel, H. M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, *17*(2), 155–167. https://doi.org/10.1016/j.gloenvcha.2006.05.002

Füssel, H. M., & Klein, R. J. T. (2006). Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change*, *75*(3), 301–329. https://doi.org/10.1007/S10584-006-0329-3/METRICS

Gebeyehu, Z., Haji, J., Berihun, T., & Molla, A. (2022). Urban Expansion Impact on Peri-urban Farm Households Welfare in Metropolitan Cities of Amhara National Regional State, Ethiopia. *Ecology, Environment and Conservation*, *28*(1), 33–44. https://doi.org/10.53550/eec.2022.v28i01.005

Getachew, B., & Manjunatha, B. R. (2021). Climate change projections and trends simulated from the CMIP5 models for the Lake Tana sub-basin, the Upper Blue Nile (Abay) River Basin, Ethiopia. *Environmental Challenges*, *5*, 100385. https://doi.org/10.1016/J.ENVC.2021.100385

Getu, K., & Bhat, H. G. (2024). Quantifying Spatio-temporal dynamics of land surface temperature for the rapidly growing city of Bahir Dar, Northwest Ethiopia using multidated Landsat data. *Physics and Chemistry of the Earth*, *134*(August 2022), 103543. https://doi.org/10.1016/j.pce.2024.103543

Goldkuhl, G. (2011). Meanings of Pragmatism: Ways to conduct information systems research. *Action in Language, Organisations and Information Systems*. https://www.researchgate.net/publication/246789082

Göpfert, C., Wamsler, C., & Lang, W. (2019). A framework for the joint institutionalization of climate change mitigation and adaptation in city administrations. *Mitigation and Adaptation Strategies for Global Change*, *24*(1), 1–21. https://doi.org/10.1007/S11027-018-9789-9/FIGURES/2

Howe, G., & McKay, A. (2007). Combining Quantitative and Qualitative Methods in Assessing Chronic Poverty: The Case of Rwanda. *World Development*, *35*(2), 197–211. https://doi.org/10.1016/J.WORLDDEV.2005.10.017

Huang, X., Huang, X., He, Y., & Yang, X. (2017). Assessment of livelihood vulnerability of land-lost farmers in urban fringes: A case study of Xi'an, China. *Habitat International*, *59*, 1–9. https://doi.org/10.1016/j.habitatint.2016.11.001

Iddrisu, S., Abass, K., Serbeh, R., Dumedah, G., Kwadwo, A., Alhassan, J., Kpevu, G. A., & Gyasi, R. M. (2025). Urban expansion and livelihood dynamics in peri-urban Tamale, Ghana. *Geographical Research*, *63*(1), 40–58. https://doi.org/10.1111/1745-5871.12681;REQUESTEDJOURNAL:JOURNAL:17455871;WGROUP:STRING:PUBLICATION

Idris, M., Kosa, A., & Juhar, N. (2020). Economic linkage between urban development and livelihood of peri-urban farming communities in Ethiopia (policies and practices). *Agricultural and Food Economics*, *8*(1). https://doi.org/10.1186/s40100-020-00164-2

IPCC. (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of ... - Intergovernmental Panel on Climate Change. Working Group II. - Google Books. In *Cambridge University Press.* Cambridge University Press. https://books.google.com/books?

IPCC. (2007). Climate Change 2007 - Impacts, Adaptation and Vulnerability: Working Group ... - Google Books. In M. L. Parry (Ed.), *Cambridge University Press.* (Vol. 4). Cambridge University Press. https://books.google.com.et/books?

IPCC. (2022a). Climate Change 2022 : Impacts, Adaptation and Vulnerability. In *Working Group II Contribution to the sixth Assessment Report of the IPCC*. Cambridge University Press. https://doi.org/10.1017/9781009325844

IPCC. (2022b). IPCC, 2022: Summary for Policy Makers. *Climate Change 2022: Impacts, Adaptation and Vulnerability*, 1–40. www.ipcc.ch

Jordan, A. (2018). Governing Climate Change: Polycentricity in Action? *Governing Climate Change*. https://doi.org/10.1017/9781108284646

Keenan, J. M., Chu, E., & Peterson, J. (2019). From funding to financing: perspectives shaping a research agenda for investment in urban climate adaptation. *International Journal of Urban Sustainable Development*, *11*(3), 297–308. https://doi.org/10.1080/19463138.2019.1565413;REQUESTEDJOURNAL:JOURNAL:

TJUE20;WGROUP:STRING:PUBLICATION

Kelly, P. M., & Adger, W. N. (2000). Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, *47*(4), 325–352. https://doi.org/10.1023/A:1005627828199/METRICS

Leeson, G. W. (2018). The Growth, Ageing and Urbanisation of our World. *Journal of Population Ageing 2018 11:2*, *11*(2), 107–115. https://doi.org/10.1007/S12062-018-9225-7

Levers, M. J. D. (2013). Philosophical Paradigms, Grounded Theory, and Perspectives on Emergence. *SAGE Opeen*, *3*(4). https://doi.org/10.1177/2158244013517243

Mekonen, A. A., & Berlie, A. B. (2021). Rural households' livelihood vulnerability to climate variability and extremes: a livelihood zone-based approach in the Northeastern Highlands of Ethiopia. *Ecological Processes*, *10*(1). https://doi.org/10.1186/s13717-021-00313-5

Mekonnen, G. T., Berlie, A. B., Legesse, S. A., & Wubie, M. A. (2023). The implication of climate change in causing urban heat island in Gondar City, Ethiopia: an analysis made using Mann–Kendall's trend test and homogeneity test. *Arabian Journal of Geosciences*, *16*(12). https://doi.org/10.1007/s12517-023-11739-w

Michaelowa, K., & Michaelowa, A. (2019). Transnational Climate Governance Initiatives: Designed for Effective Climate Change Mitigation? *The Comparative Politics of Transnational Climate Governance*, 146–178. https://doi.org/10.4324/9781351135436-6

Mohiuddin, G., & Mund, J.-P. (2024). Spatiotemporal Analysis of Land Surface Temperature in Response to Land Use and Land Cover Changes : A Remote Sensing Approach. *Remote Sensing Article*.

Myers, G. (2021). Urbanisation in the Global South. *Cities and Nature*, *Part F337*, 27–49. https://doi.org/10.1007/978-3-030-67650-6_2

Nabatchi, T., & Emerson, K. (2023). Collaborative Governance Regimes. *Collaborative Governance Regimes*. https://doi.org/10.1353/BOOK44406

Ngu, N. H., Tan, N. Q., Non, D. Q., Dinh, N. C., & Nhi, P. T. P. (2023). Unveiling urban households' livelihood vulnerability to climate change: An intersectional analysis of Hue City, Vietnam. *Environmental and Sustainability Indicators*, *19*(June), 100269. https://doi.org/10.1016/j.indic.2023.100269

Nguyen, T. T. X., Bonetti, J., Rogers, K., & Woodroffe, C. D. (2016). Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. *Ocean & Coastal Management*, *123*, 18–43. https://doi.org/10.1016/J.OCECOAMAN.2015.11.022

Nhamo, L., Rwizi, L., Mpandeli, S., Botai, J., Magidi, J., Tazvinga, H., Sobratee, N., Liphadzi, S., Naidoo, D., Modi, A. T., Slotow, R., & Mabhaudhi, T. (2021). Urban nexus and transformative pathways towards a resilient Gauteng City-Region, South Africa. *Cities*, *116*, 103266. https://doi.org/10.1016/J.CITIES.2021.103266

North, D. C. (1990). Institutions, Institutional Change and Economic Performance. *Institutions, Institutional Change and Economic Performance*. https://doi.org/10.1017/CBO9780511808678

O'Brien, K., Eriksen, S., Nygaard, L. P., & Schjolden, A. (2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, *7*(1), 73–88. https://doi.org/10.1080/14693062.2007.9685639

OECD, AfDB, UNOPS-Cities Alliance, & UCLG Africa. (2025). Africa's Urbanisation Dynamics 2025: Planning for Urban Expansion. *West African Studies*. https://doi.org/10.1787/2a47845c-en

Ofgeha, G. Y. (2021). Land-Use Dynamics And Climate Variability: Local Processes, And Livelihood Implications On Small-Scale Farmers In Anger Watershed, Southwestern Ethiopia. In *Dissertation*. Addis Ababa, Ethiopia.

Pasquini, L. (2020). The urban governance of climate change adaptation in least-developed African countries and in small cities: the engagement of local decision-makers in Dar es Salaam, Tanzania, and Karonga, Malawi. *Climate and Development*, *12*(5), 408–419. https://doi.org/10.1080/17565529.2019.1632166

Poth, C. N. (2018). Innovation in Mixed Methods Research : A Practical Guide to Integrative Thinking with Complexity. *Sage Publications Ltd.*, 1–384.

Ricci, L. (2012). Peri-Urban Livelihood and Adaptive Capacity: Urban Development in Dar Es Salaam. *Consilience: The Journal of Sustainable Development*, *7*(1), 46–63. http://journals.cdrs.columbia.edu/consilience/index.php/consilience/article/view/206/93

Sahana, M., Ravetz, J., Patel, P. P., Dadashpoor, H., & Follmann, A. (2023). Where Is the Peri-Urban? A Systematic Review of Peri-Urban Research and Approaches for Its Identification and Demarcation Worldwide. *Remote Sensing 2023, Vol. 15, Page 1316*, *15*(5), 1316. https://doi.org/10.3390/RS15051316

Saleem, H., Ahmed, R., Mushtaq, S., Saleem, S., & Rajesh, M. (2024). Remote sensing-based analysis of land use, land cover, and land surface temperature changes in Jammu District, India. *International Journal of River Basin Management*. https://doi.org/10.1080/15715124.2024.2327493

Seto, K. C., Dhakal, S., & Bigio, A. (2014). Human Settlements, Infrastructure, and Spatial Planning. *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer,*. https://escholarship.org/uc/item/7kz997d2

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(40), 16083–16088. https://doi.org/10.1073/PNAS.1211658109/SUPPL_FILE/PNAS.201211658SI.PDF

Shanks, G. (2002). Guidelines for Conducting Positivist Case Study Research in Information Systems. *Australasian Journal of Information Systems*, *10*(1), 76–85. https://doi.org/10.3127/ajis.v10i1.448

Shi, H., Xian, G., Auch, R., Gallo, K., & Zhou, Q. (2021). Urban Heat Island and Its Regional Impacts Using Remotely Sensed Thermal Data—A Review of Recent Developments and Methodology. *Land 2021, Vol. 10, Page 867*, *10*(8), 867. https://doi.org/10.3390/LAND10080867

Solorio, I. (2021). Leader on paper, laggard in practice: policy fragmentation and the multi-level paralysis in implementation of the Mexican Climate Act. *Climate Policy*, *21*(9),

1175–1189. https://doi.org/10.1080/14693062.2021.1894084

Talema, A. H., & Nigusie, W. B. (2023). Impacts of urban expansion on the livelihoods of local farming communities: The case of Burayu town, Ethiopia. *Heliyon*, *9*(3), e14061. https://doi.org/10.1016/j.heliyon.2023.e14061

Terfa, B. K., Chen, N., Liu, D., Zhang, X., & Niyogi, D. (2019). Urban Expansion in Ethiopia from 1987 to 2017: Characteristics, Spatial Patterns, and Driving Forces. *Sustainability 2019, Vol. 11, Page 2973*, *11*(10), 2973. https://doi.org/10.3390/SU11102973

Tessema, M. W. (2017). Impact of Urban Expansion on Surrounding Peasant Land the Case of Boloso Sore Woreda, Areka Town, SNNPR, Ethiopia. *Global Journal of Human-Social Science*, *17*(2), 1–15.

UNDP. (2011). Governance Principles, Institutional Capacity and Quality. In *Towards sustaining MDG progress (Chapter 8)*. UNDP.

United Nations Department of Economic and Social Affairs Population Division. (2019). World Urbanization Prospects. *Demographic Research*, *12*, 126. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

Wilby, R. L. (2008). *Constructing Climate Change Scenarios of Urban Heat Island Intensity and Air Quality*. *35*(5), 902–919. https://doi.org/10.1068/B33066T

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2014). At risk: natural hazards, peoples vulnerability and disasters. *At Risk: Natural Hazards Peoples Vulnerability and Disasters*, 1–471. https://doi.org/10.4324/9780203714775

World Bank. (2011). Institutional Capacities and Their Contributing Characteristics for Institutional Diagnostics, Program Design and Results Management. In *World Bank Institute*. https://documents1.worldbank.org/curated/en/249381467986349471/pdf/80636-WP-Institutional-Capacities-Feb-11-Box-377295B-PUBLIC.pdf

World Data Atlas. (2022). *Ethiopia Urban population, 1960-2022*. Knoema. https://knoema.com/atlas/Ethiopia/Urban-population

Xu, H. (2008). A new index for delineating built-up land features in satellite imagery. *International Journal of Remote Sensing*, *29*(14), 4269–4276. https://doi.org/10.1080/01431160802039957

Yeneneh, M. F., Semahagne, H. S., Birhanu, T. A., & Benti, T. R. (2024). Factors Influencing Peri-Urban Land Development in Ethiopia: Evidences from Assosa City. *International Journal of Environmental Protection and Policy 2024, Volume 12, Page 105*, *12*(4), 105–121. https://doi.org/10.11648/J.IJEPP.20241204.12

CHAPTER 2

2. URBANIZATION AND LAND SURFACE TEMPERATURE DYNAMICS IN BAHIR DAR, ETHIOPIA: A COMPARATIVE ANALYSIS OF PRE- AND POST-CAPITAL STATUS

Based on publication:

Melese, M., Anteneh, M., & Bantigegn, S. (2025). Urbanization and land surface temperature dynamics in Bahir Dar, Ethiopia: a comparative analysis of pre- and post-capital status. Frontiers in Environmental Science, April, 1–18. https://doi.org/10.3389/fenvs.2025.1569636

Abstract

Rapid urbanization alters LULC patterns, affecting LST and intensifying the UHI effect. However, few studies have examined the long-term thermal impacts of urban expansion, particularly pre- and post-capital designation effects in rapidly growing cities like Bahir Dar, Ethiopia. This study analyzes LULC changes and LST dynamics from 1984 to 2024 using remote sensing and geospatial techniques. Supervised classification with the maximum likelihood algorithm was applied to Landsat imagery to classify LULC into five categories. LST was retrieved from thermal infrared bands and analyzed with normalized difference vegetation index (NDVI), built-up index (NDBI), and water index (MNDWI) to assess urban heat variations. The findings reveal a 366% expansion of built-up areas, along with a 26.8% decline in agricultural land and 34.2% in wetlands. Before 1994, vegetation and wetlands moderated LST, with an LST-NDVI correlation of -0.069 (1984), which weakened to -0.0549 (2024). LST-MNDWI correlation dropped from -0.1409 to -0.0588, while LST-NDBI shifted from 0.0831 to 0.0235. These results highlight the need for climate-sensitive urban planning. Expanding green infrastructure, restoring wetlands, and adopting climate-adaptive policies are crucial for managing UHI effects in rapidly urbanizing cities. This study offers insights for policymakers and urban planners to enhance climate resilience in Bahir Dar and similar cities.

Keywords: Capital designation, Land surface temperature, Urban expansion, Urban heat island, Bahir Dar city.

2.1. Introduction

In the time of rapid urban development, the world has witnessed a record trend of urbanization. Globally over half the population is urban and projected nearly 70% by 2050 largely driven by developing countries (Dodman et al., 2022; UNECA, 2022). Africa exemplifies this as its population is projected to double by 2050 adding 950 million urban inhabitants (Brenner, 2013; UNECA, 2018). Ethiopia has rapid urbanization rates between 4.1% (CSA, 2018) and 5.4% (World Bank, 2015). Urban population increased from 9.1% to 22.7% over the last five decades (World Data Atlas, 2022), with projections reaching 42% by 2050 (Tessema, 2017). These rapid urban growth trends and the resulting land cover changes in developing nations transform rural landscapes into urban areas (Eshetie, 2024; Kindu et al., 2020).

The 2030 projected doubling of global urban land underscores the importance of understanding LULC changes for effective urban planning (Seto et al., 2012). Land use reflects human modifications to the land, while land cover refers to its physical features (Foley et al., 2005). Remote sensing techniques have proven invaluable for tracking LULC transformations in developing cities (Din & Mak, 2021; Saleem et al., 2024), particularly in the absence of consistent in-situ monitoring. These approaches facilitate the assessment of urban sprawl, vegetation loss, and surface temperature variations, all of which impact urban resilience and sustainability.

Urbanization drives LULC changes, replacing vegetation with artificial surfaces, which increases LSTs and intensifies the UHI effect (Balew and Korme, 2020; Fan and Wang, 2020). This UHI effect, characterized by higher urban temperatures compared to rural areas, negatively impacts residents' well-being (Mekonnen et al., 2023; Simwanda et al., 2019). For instance, Saleem et al. (2024) found a strong inverse correlation between NDVI and LST, reinforcing the critical role of green spaces in mitigating urban heat islands. Similarly, Din and Mak (2021) demonstrated that built-up expansion in Hyderabad significantly contributed to land degradation and temperature anomalies.

LST, a critical indicator of surface energy balance, varies with land characteristics and significantly affects climate, air quality, and public health (Meng et al., 2022; Shreevastava et al., 2019). Analyzing LULC and LST changes is thus essential for understanding urban climate impacts, informing sustainable planning, and enhancing urban liveability. Since becoming the regional capital in 1994, Bahir Dar's population has increased from 54,766 in 1984 to nearly 500,000 by 2020 and is projected to reach 4 million by 2063 (Bahir Dar City Structural Plan

Preparation Project Office, 2020; CSA, 1995). This has led to rapid expansion which is transforming Bahir Dar's LULC, increasing LST and intensifying the UHI (Wubie et al., 2020), thus highlighting the need for adaptive urban planning.

Unlike studies in other Ethiopian cities such as Addis Ababa (Balew & Semaw, 2022), Nekemte and Jimma (Dibaba, 2023), or Jimma alone (Moisa et al., 2022), this study addresses Bahir Dar's unique environmental context near Lake Tana and the Abay River. Prior LST studies in the city often observed limited indices such as Debebe and Miteku (2023) used the NDVI but overlooked NDBI. Similarly, Balew and Korme (2020) and Getu and Bhat (2024) included NDVI and NDBI but overlooked water/wetland-related indices like the NDWI critical for assessing thermal effects of water/wetlands (Mohiuddin & Mund, 2024).

This study adopts a holistic approach by linking LST to indices measuring vegetation (NDVI), built-up areas (NDBI), and water/wetland characteristics. Higher NDVI values reflect denser vegetation, while elevated NDBI values signal urban growth (Arulbalaji & Gurugnanam, 2014). Instead of the standard NDWI, the modified NDWI (MNDWI) as proposed by Xu (2008) is used for better accuracy in assessing impacts of LULC on water/wetland and LST. This comprehensive focus fills critical gaps in prior LST studies of Bahir Dar's unique urban environment. Additionally, studies such as Ibrahim et al. (2020) have emphasized the role of land use dynamics in shaping economic and social transformations in emerging cities. Their findings align with the patterns observed in Bahir Dar, where the interplay of rapid urbanization, policy changes, and infrastructural development continues to reshape the city's landscape. Integrating these perspectives strengthens the relevance of this study within the broader discourse on LULC transformations in rapidly developing cities.

To address this gap, this study examines the spatial and thermal consequences of Bahir Dar's rapid administrative transition by specifically comparing LULC and LST changes across the pre-capital (1984-1994) and post-capital (1994-2024) eras. By using the 1994 capital designation as a specific policy-driven temporal anchor, this approach allows for a localized assessment of how political and administrative status accelerates environmental and microclimatic transformations in a secondary city context. For example, Sidama Region, Southwestern Ethiopia Peoples Region and Central Ethiopia Region with capital were new regions created after 2018 (Ethiopia Peace Observatory, 2024). The study does not position itself on the formation of new regions but recognizes the need to remain sensitive to the following environmental implications. Additionally, it includes the often omitted 2002-2008

period by applying destripping techniques to poor Landsat 7 ETM+ data. Using remote sensing data, the study covers Bahir Dar's transformation from 1984 to 2024, filling a key gap in the literature and offering insights for sustainable urban planning, resilience, and climate change mitigation.

2.2. Methods and materials

2.2.1. Study area description

Bahir Dar has its history dating back to the 14th century with the establishment of St. Kidane Miheret Church (Appelhans, 2017). It was thus named due to its location close to Lake Tana and Blue Nile. Urbanization started during Italian occupation (1936-1941) and accelerated during the post-liberation (1941-1974) (Seyoum, 2014). The city was declared ANRS capital in 1994 (Haregeweyn et al., 2012). The city is famous for tourist destinations such as Blue Nile Falls and Lake Tana Monasteries, and it has been a UNESCO site of biodiversity since 2015 (Stave et al., 2017). The city's area is around 230 km², latitudes 11° 25' 11" to 11° 58' 11" N and longitudes 37° 2' 2" to 37° 42' 4" E (Figure 2.1). It is 567 km away from Addis Ababa. It lies between 1,708 and 2,007 meters above sea level. It is flat but has very steep slopes by the River Abay.

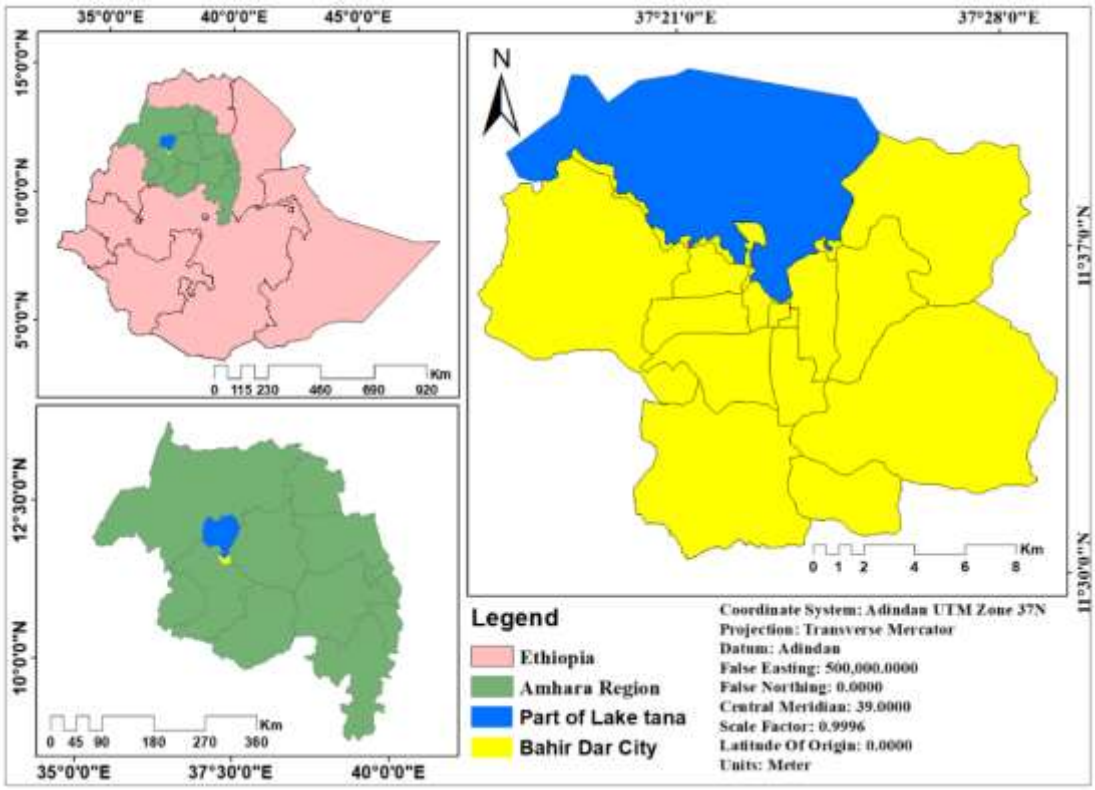


Figure 2.1 Map of the study area

The climate of Bahir Dar features remarkable variability, with daytime temperatures varying from very cold months in January (18.48°C) and February (20.44°C) to very hot months in March (21.83°C) and April (22.06°C) while peaking at 28.55°C. Rainfall is more seasonal and peaks from around June to August with more than 400 mm of rainfall per month, while the rest of the year is frequently dry and proves detrimental to agriculture. The economic activities of horticulture, agro-industrial processing, and tourism, under the aegis of attractions like Lake Tana and the Blue Nile, promote the development of the city (Seyoum, 2014; UNESCO, 2015).

2.2.2. Data Sources and Collection Tools

For the span of 40 years between 1984 and 2024, Landsat images obtained from the USGS Earth Explorer database were used to track the changes in LULC and the consequent LST effects. Landsat images were chosen in consideration of their wide spatial coverage, a resolution of 30 m, and ease of accessibility (Khun et al., 2021; Nayak, 2021). Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI/TIRS images of 1984, 1994, 2004, 2014, and 2024 were selected for their quality and consistency (Table 2.1), with 10-year intervals based on established LULC analysis practices (Debebe & Miteku, 2023; Gazi et al., 2021; Moisa et al., 2022). While the 30-meter resolution of Landsat is standard for city-wide studies, it is acknowledged that very small green spaces or individual buildings may be averaged into a single pixel.

Table 2.1 Satellite data and bands for LULC and LST analysis

Year	Satellite & Sensor	Date	Bands for		Wavelength (micrometres) LULC/LST
			LULC	LST	
1984	Landsat 5 TM	December 31	1-5	6	0.45-2.35/10.40-12.50 (TM)
1994	Landsat 5 TM	January 25	1-5	6	0.45-2.35/10.40-12.50 (TM)
2004	Landsat 7 ETM+	February 14	1-5, 7	6	0.45-2.35/10.40-12.50 (ETM+)
2014	Landsat 8 OLI/TIRS	February 1	2-7	10	0.45-2.35/10.6-11.2 (OLI)
2024	Landsat 8 OLI/TIRS	January 12	2-7	10	0.45-2.35/10.6-11.2 (OLI)

Preprocessing steps included layer stacking, subsetting, geometric/radiometric correction, and projection onto UTM Zone 37N (WGS84) were done and images (path 170, row 052) were acquired during the dry season to minimize seasonal variations (Alemayehu et al., 2023a; Nega & Balew, 2022). Key indices of NDVI, NDBI, and MNDWI quantified urban expansion and LULC impacts on LST. Demographic data were obtained from CSA, Bahir Dar Revenue Office, and Structural Plan Preparation Project Office, providing context on urbanization

pressures. Topographic maps, aerial photos, and GPS-enhanced high-resolution images supported LULC classifications and spatial accuracy. This integrated dataset captures Bahir Dar's transformation from 1984 to 2024, addressing research gaps through advanced indices and offering insights for sustainable urban planning and climate adaptation.

2.2.3. Methods of Data Analysis

2.2.3.1. LULC change analysis

This study employed a supervised image classification approach using the maximum likelihood classifier (MLC) to accurately identify and map land cover classes over time. The MLC method was chosen due to its statistical robustness in minimizing classification errors by considering class covariance matrices and mean vectors (Teshome et al., 2022; Yesuph & Dagnew, 2019). Five major LULC categories were identified; water bodies, wetlands, vegetation, agricultural land, and built-up areas (Table 2.2).

Table 2.2 LULC change categories and their descriptions

LU classes	Descriptions
Waterbody	Refers to river and stream courses, lakes, ponds and open water in the wetland
Wetland	Areas consisted of papyrus and phragmites, Swampy areas, meadows, either seasonal or permanent waterlogged
Vegetation	Forest, Grassland, shrubland, woodland, Reperian vegetation, and plantation
Agricultural land	Cropland, fallow land, Pastureland, and bare land
Built-Up	Areas with all types of artificial surfaces including Built-up, asphalt and concrete roads, parking lots and industrial zones

Source: (Alemayehu et al., 2023a; Assefa et al., 2022; Balew & Korme, 2020; Fitawok et al., 2020)

To ensure high classification accuracy, training samples for each land cover class were selected based on prior knowledge, visual interpretation of satellite images, and reference data where available. The classification process was further refined through post-classification corrections, including manual editing and the use of ancillary data such as Google Earth imagery. The accuracy of the classification results was assessed using confusion matrices, overall accuracy, producer's accuracy, and user's accuracy, along with kappa statistics to evaluate classification reliability.

To detect and quantify LULC changes, change detection analysis was performed by comparing classified images from different years. This enabled the identification of spatial and temporal

trends in land cover transformation. The impact of urban expansion on LST was examined using correlation analysis with the NDVI, NDBI, and MNDWI to assess relationships between LULC changes and surface temperature variations (Figure 2.2).

The spatial and image analyses, including classification and change detection, were conducted using ArcGIS 10.8 and ERDAS Imagine 2015, while statistical analysis and data visualization were performed using SPSS 20 and Microsoft Excel. These tools facilitated the interpretation of land cover transitions and their effects on the thermal landscape of Bahir Dar City.

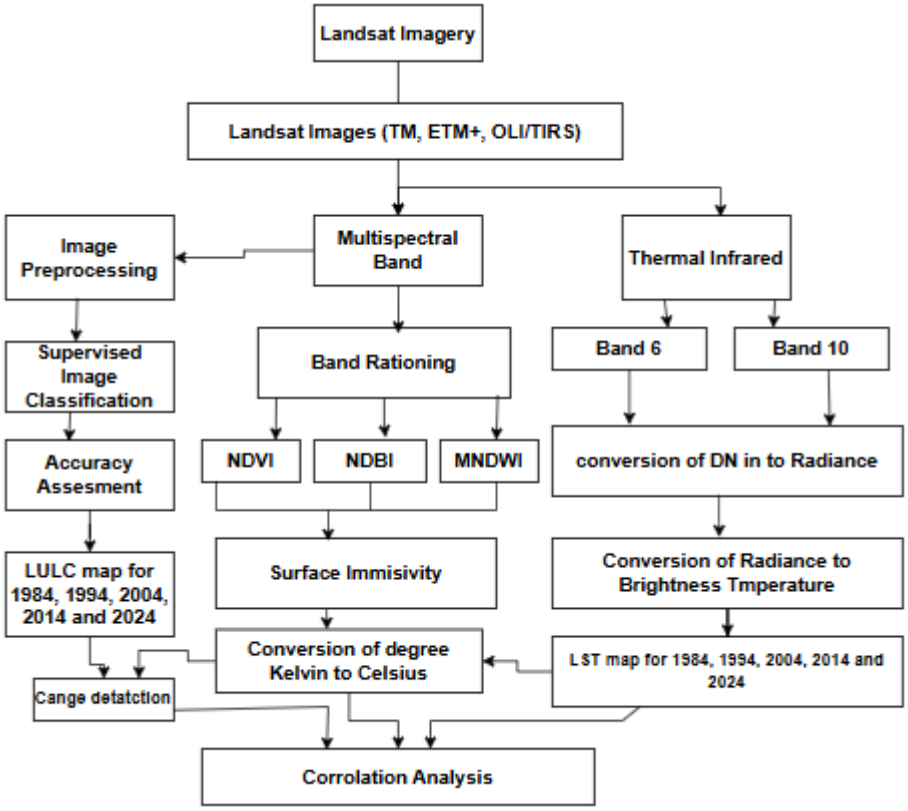


Figure 2.2 Methodological flow chart of the study

2.2.3.2. LST retrieval

LST data were extracted from Landsat thermal bands by converting digital numbers into temperature values. Thermal band 10 (Landsat 8) and band 6 (Landsat 5 and 7) were used (Table 2.1). LST calculation followed methods by Dibaba (2023), Hassan et al. (2021) and Alemayehu et al. (2023), and Debebe and Miteku (2023).

Step I: Conversion of Digital Numbers into Radiance

The first step in LST determination converts digital numbers into at-sensor radiance to calculate brightness temperature for Landsat 5 and 7 images via (Equation (1).

$$L\lambda = \frac{LMAX\lambda - LMIN\lambda}{QCALMAX - QCALMIN} \times (QCAL - QCALMIN) + LMIN\lambda \quad (1)$$

Where

$L\lambda$ = Spectral radiance received by the sensor (W/(m2 × sr × μm))

$QCAL$ = the quantized calibrated pixel value in the DN

$LMIN\lambda$ = the spectral radiance that is scaled to $QCALMIN$ (W/(m^2 × sr × μm)).

$LMAX\lambda$ = the spectral radiance that is scaled to $QCALMAX$ (W/(m^2 × sr × μm)).

$QCALMIN$ = the minimum quantized calibrated pixel value (corresponding to $LMIN\lambda$ in DN), which is 1

$QCALMAX$ = the maximum quantized calibrated pixel value (corresponding to $LMAX\lambda$) at DN =255.

For Landsat 8, to calculate the ratio of the digital number to radiance, the TIRS of band 10 was converted to spectral radiance via Equation (2.

$$L\lambda = (ML \times QCaL) + AL \quad (2)$$

Where

$L\lambda$ = the top of atmosphere (TOA) spectral radiance (Wm - 2 sr -1 μm -1)

ML = the band-specific multiplicative rescaling factor from the metadata (radiance multiband x, where x is the band number)

AL = the band-specific additive rescaling factor from the metadata (radiance–addband x, where x is the band number); and

QCaL = quantized and calibrated standard product pixel values (DN).

Step II: Convert to brightness temperature

The mono-window algorithm calculated LST using land surface emissivity, atmospheric transmissivity, brightness temperature, and average atmospheric temperature (Qin et al., 2001). Band 6 TM and ETM+ values were adjusted from spectral radiance to temperature using the Planck function (Chander et al., 2009), (Equation (3).

$$T = \frac{K2}{ln(\frac{k1}{L\lambda}+1)} \quad (3)$$

Where

T is the effective satellite temperature in Kelvin,

K2 is the calibration constant 2,

K1 is the calibration constant 1,

Lλ is the spectral radiance in watts/(meter squared×ster×μm).

ln: the natural logarithm

It uses the brightness temperatures of band 10 of Landsat 8 to compute the mean land surface emissivity and then estimates the LST. The mean value of the land surface emissivity (LSE) of the thermal infrared (TIR) bands is given by Equation (4.

$$\boldsymbol{BT} = \frac{\boldsymbol{K2}}{\boldsymbol{ln}(\frac{\boldsymbol{k1}}{\boldsymbol{L\lambda}}+\boldsymbol{1})} \quad (4)$$

Where

BT is the effective at-sensor brightness temperature (K),

K2 is the calibration constant 2 (K),

K1 is the calibration constant 1 (W/(m2 × sr × μm)).

Lλ is the spectral radiance at the sensor aperture (W/(m2×sr× μm)), and

ln: the natural logarithm

Step III: land surface emissivity estimation

The emissivity is calculated via Equation (5.

$$\varepsilon = 0.004 \times Pv + 0.986 \quad (5)$$

Where Pv is the vegetation proportion acquired according to Equation (6.

$$\boldsymbol{Pv} = \left[\frac{\boldsymbol{NDVI-NDVImin}}{\boldsymbol{NDVImax+NDVImin}}\right]^{\boldsymbol{2}} \quad (6)$$

The computed LST is corrected for emissivity via Equation (7.

$$\boldsymbol{LST} = \frac{\boldsymbol{TB}}{\boldsymbol{1+\left(L\lambda\frac{TB}{P}\right)In\varepsilon}} \quad (7)$$

Where

LST = the land surface temperature (in Kelvin),

TB = the radiant surface temperature (in Kelvin), and

λ = the wavelength of the emitted radiance (10.8 μm).

$P = h * \frac{c}{\sigma}$ $(1.438 \times 10^{-2}\ mK)$

h = Planck's constant (6.26× 10^{-34} J s),

c = the velocity of light (2.998× 108 m/s),

σ = Stefan Boltzmann's constant (1.38× 10^{-23} J K^{-1}), and

ε = the land surface emissivity.

Finally, 273.15 was subtracted from the Landsat TM, ETM^{+}, and OLI/TIRS LST measurements for conversion to degrees Celsius (Equation (8).

$$°C = K - 273.15 \quad (8)$$

Where, °C is the LST in degrees Celsius and K is the LST in Kelvin.

2.2.3.3. Estimation of the NDVI, NDBI and MNDWI

The NDVI was calculated using red and near-infrared bands from Landsat 5, 7, and 8 (Levin, 2000). Specifically, bands 3 and 4 for Landsat 5 and 7, and bands 4 and 5 for Landsat 8. Low red reflectance indicates stressed vegetation, while high NIR reflectance shows healthy vegetation (Nega & Balew, 2022; A. Pandey, Mondal, & Guha, 2024). NDVI reduces LST and mitigates UHIs (Mekonnen et al., 2023), calculated using via Equation (9.

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad (9)$$

Gazi et al. (2021) suggested that Landsat 5 and 7 multispectral bands be computed from bands 4 and 5 and that Landsat 8 multispectral bands from bands 5 and 6 be computed to calculate the NDBI. Isioye et al. (2020) described this method as achieving 92% accuracy in mapping densely populated areas. The NDBI is calculated via Equation (10.

$$NDBI = \frac{MIR-NIR}{MIR+NIR} \quad (10)$$

Where, NDBI is the normalized difference built-up index, MIR is the middle infrared, and NIR is the near-infrared.

In addition, the MNDWI is calculated to more accurately identify and monitor water bodies and wetlands, which are key in moderating local temperatures and influencing LST (Xu, 2008). The MNDWI uses the green and shortwave infrared (SWIR) bands of Landsat imagery, specifically bands 2 and 5 for Landsat 5 and 7 and bands 3 and 6 for Landsat 8. The MNDWI is calculated via Equation (11.

$$MNDWI = \frac{(Green-SWIR)}{(Green+SWIR)} \quad (11)$$

Where, MNDWI is the modified normalized difference water index, Green represents the green band, and SWIR is the shortwave infrared band. These indices (NDVI, NDBI and MNDWI) provide a more refined analysis of vegetation, urban and wetland/water body features, which are essential for accurately assessing LST variations.

2.2.3.4. Correlation analysis

Correlation analysis quantified the relationships between LST and NDVI, NDBI, and MNDWI using Equation (12).

$$\boldsymbol{LST = \beta_0 + \beta_1(NDVI) + \beta_2(NDBI) + \beta_3(MNDWI) + \epsilon} \quad (12)$$

Here, LST represents land surface temperature (dependent variable), while NDVI, NDBI, and MNDWI (independent variables) denote vegetation cover, built-up areas, and water bodies/wetlands, respectively. β_0 is the intercept, β_1, β_2, and β_3 are the coefficients, and ϵ is the error term. This model highlights how NDVI, NDBI, and MNDWI variations influence LST, offering insights into the environmental effects of urban expansion and changes in vegetation and water bodies.

2.2.3.5. Accuracy assessment

An accuracy assessment was conducted to evaluate the precision of the classified land cover maps and LST retrievals. This assessment involved comparing the classified images with ground truth data or higher-resolution imagery to determine classification accuracy and error rates. The ground truth data were obtained through Google Earth, field visits, and historical records. High-resolution Google Earth images, Bahir Dar city master plans, and aerial photos served as reference data for land-use classification during the accuracy assessment of the supervised classification. To quantify classification accuracy, statistical metrics including user accuracy, producer accuracy, overall accuracy, and kappa statistics were employed. These metrics provide a comprehensive evaluation of classification reliability and agreement with reference data.

2.3. Results and Discussion

2.3.1. Land Use-Land Cover Changes and Urban Expansion

LULC maps for Bahir Dar city were created for 1984, 1994, 2004, 2014, and 2024. Map accuracy was assessed using user accuracy, producer accuracy, overall accuracy, and kappa statistics, reflecting classification reliability. Overall accuracies were 88.32%, 89.67%, 91.15%, 92.58%, and 93.76%, with kappa values of 0.87, 0.89, 0.91, 0.92, and 0.94, indicating strong reliability (Foody, 2020). The 40-year analysis revealed substantial LULC changes, especially after Bahir Dar became the ANRS capital in 1994 (Figure 2.3). Urbanization, economic growth, and population increases replaced natural and agricultural areas with built-up surfaces, consistent with global urbanization trends in developing regions (Nato et al., 2023).

The area of water bodies in Bahir Dar showed a declining trend over the study period. In 1984, water bodies covered 2.71%, decreasing to 2.70% in 1994, 2.66% in 2004, 2.63% in 2014, and 2.29% in 2024 (Table 2.3). These changes reflect urban encroachment, sedimentation, and partial drying due to land use changes and urban pressures linked to Bahir Dar's growth as the regional capital. Similar trends are observed in cities like Addis Ababa and Kampala, where informal settlements and urban sprawl have reduced water body coverage (Birhanu et al., 2023; Richmond et al., 2018).

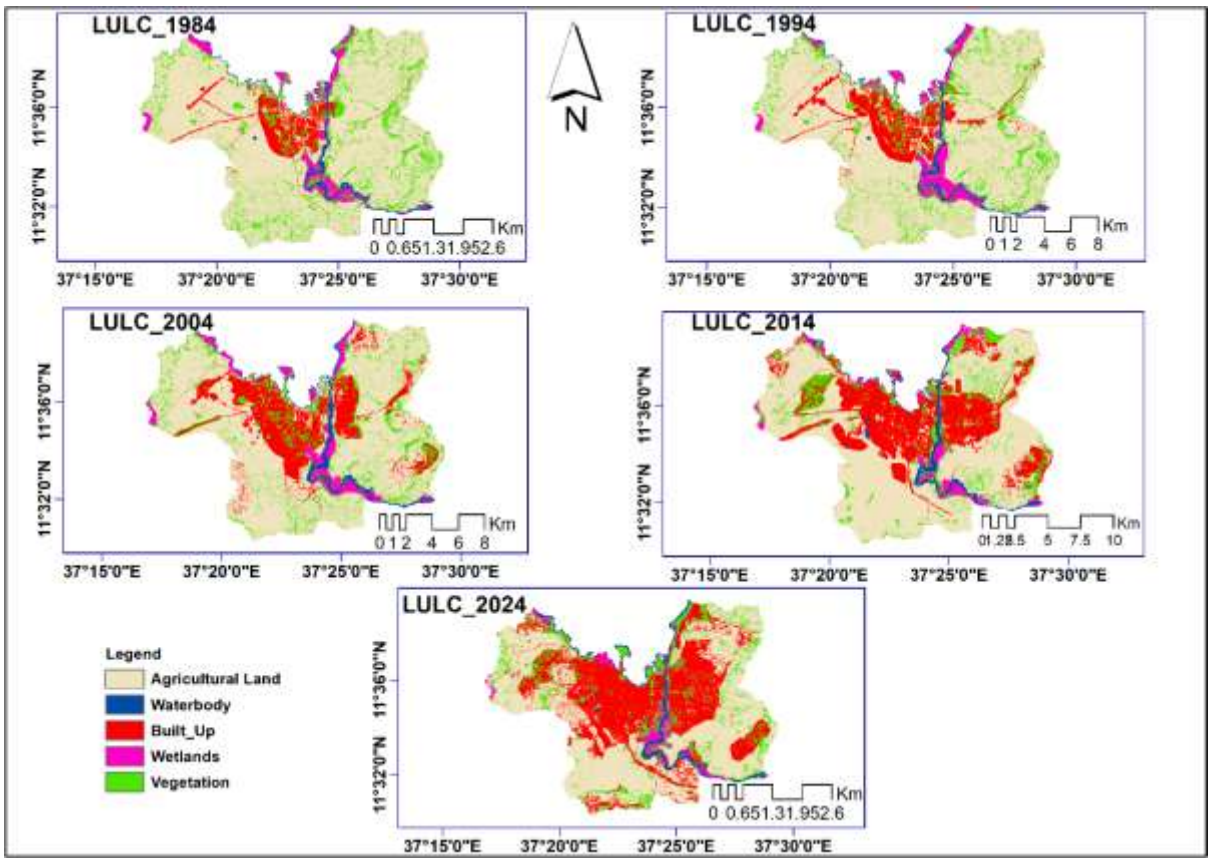


Figure 2.3 LULC maps for the years 1984, 1994, 2004, 2014, and 2024 of Bahir Dar city

Wetland areas expanded from 5.60% in 1984 to 6.20% in 1994, likely due to improved management or natural hydrological changes. However, they declined to 6.07% in 2004, 4.19% in 2014, and 3.68% in 2024, reflecting urban development pressures, especially after 1994, as wetlands were converted into residential, agricultural, or industrial zones. This degradation, consistent with findings in Nairobi (Guto, 2021), compromises critical ecosystem services like flood regulation, biodiversity, and water filtration, raising concerns about urban resilience. Wetlands, often termed "nature's kidneys," play a vital role in maintaining ecological balance.

Vegetation declined from 13.39% in 1984 to 11.51% in 2024, with a decrease to 10.78% by 2004, slight recovery to 10.79% in 2014, and modest growth by 2024, possibly due to localized conservation efforts. The long-term decline reflects urban expansion pressures, similar to patterns in Lagos and Kigali, where urban growth led to deforestation and shrinking green spaces (Adegun, 2017; Xueqin et al., 2022). Alves and Lopes (2017) noted that vegetation loss exacerbates the UHI effect by reducing shade and evapotranspiration, intensifying urban temperature increases.

Table 2.3 LULC distributions and corresponding areas

LULC types	Year									
	1984		1994		2004		2014		2024	
	area (km^2)	%	area (km^2)	%	area (km^2)	%	area (km^2)	%	area (km^2)	%
Waterbody	6.16	2.71	6.14	2.70	6.05	2.66	5.98	2.63	5.21	2.29
Wetlands	12.73	5.60	14.08	6.20	13.80	6.07	9.52	4.19	8.36	3.68
Vegetations	30.44	13.39	28.86	12.70	24.50	10.78	24.51	10.79	26.16	11.51
Agricultural Land	163.31	71.87	157.19	69.17	141.33	62.19	133.01	58.53	119.52	52.60
Built_Up	14.60	6.43	20.97	9.23	41.57	18.29	54.23	23.86	67.99	29.92
Total	227.24	100	227.24	100	227.24	100	227.24	100	227.24	100

Agricultural land, the dominant land use, declined from 71.87% in 1984 to 52.60% in 2024, reflecting urban sprawl and shifting land use priorities. The conversion of farmland into residential and commercial areas impacts food security, rural livelihoods, and hydrological cycles, similar to trends observed in Lagos, Nigeria, and Harar, Ethiopia (Dekolo et al., 2015; Worseme, 2004). Built-up areas expanded significantly from 6.43% in 1984 to 29.92% in 2024, a 366% increase, driven by Bahir Dar's urban growth and regional capital status post-1994. Similar trends are seen in cities like Hawassa, where administrative importance accelerates urbanization (Molla et al., 2024). This growth impacts the environment, increasing runoff, reducing groundwater recharge, and intensifying UHI effects.

2.3.1.1. Comparisons of Pre- and-Post capital Status (1984-1994 vs. 1994-2024)

During the precapital period (1984-1994), LULC patterns were relatively stable due to slower urbanization and modest population growth, with population increasing from 54,766 in 1984 to 96,140 in 1994 (CSA, 1984, 1995). Wetlands increased from 5.60% to 6.20%, built-up areas grew from 6.43% to 9.23%, and agricultural land slightly decreased from 71.87% to 69.17%.

Water bodies and vegetation showed minimal declines, from 2.71% to 2.70% and 13.39% to 12.70%, respectively, reflecting limited land conversion. In the postcapital period (1994-2024), rapid urbanization and population growth i.e. from 96,140 in 1994 to ~500,000 by 2020 (Bahir Dar City Structural Plan Preparation Project Office, 2020) drove significant LULC changes. Built-up areas surged from 9.23% to 29.92% (+224%), while agricultural land declined from 69.17% to 52.60%. Wetlands shrank from 6.20% to 3.68%, water bodies from 2.70% to 2.29%, and vegetation from 12.70% to 11.51%, reflecting the loss of natural landscapes to urban expansion (Figure 2.3).

The accelerated urbanization during the post-capital period (1994-2024) mirrors trends observed in other regional administrative capitals in the Global South, such as Dodoma, Tanzania, where rapid administrative transitions fundamentally reshaped natural land cover (Miringay et al., 2024). In Bahir Dar, this transition occurred without the mediating influence of sustainable spatial planning, directly explaining the severe ecological degradation documented in our findings.

The literature suggests that the absence of integrated planning interventions specifically those targeting wetland protection, green space preservation, and climate-sensitive urban layouts; is a primary driver that exacerbates UHI effects and degrades local microclimates (Corbella et al., 2011). While model cities like Curitiba, Brazil, historically demonstrated that integrating ecological conservation with spatial development can stabilize microclimatic warming and preserve wetland functions (Rabinovitch, 1992), Bahir Dar's post-capital trajectory represents a laissez-faire developmental path. The dramatic loss of vegetation and wetlands, alongside the sharp rise in surface temperatures across all built-up classes, is a direct physical consequence of this unmitigated, administratively-driven expansion.

2.3.2. Land surface temperature trends in Bahir Dar city (1984 - 2024)

Over four decades, Bahir Dar's LST showed a significant rise in mean and maximum temperatures, driven by urbanization and land use changes. In 1984, the mean LST was 28.22°C, with a maximum of 35.25°C (Table 2.4), reflecting moderate thermal conditions due to dominant vegetated and agricultural land. By 1994, the mean LST rose to 28.81°C, with a maximum of 36.44°C, coinciding with Bahir Dar's designation as the regional capital. This marked the start of infrastructure development, including roads, government offices, and housing (Figure 2.4). Similar trends are seen globally, such as in Kigali, Rwanda, where early

urbanization phases led to a 2°C rise in surface temperatures due to infrastructure expansion (Safari et al., 2024).

Between 1994 and 2004, the mean LST rose sharply to 31.08°C, with a maximum of 39.56°C, marking a 2.27°C increase. Similar trends occurred in Accra, Ghana, where rapid urbanization replaced vegetation with impervious surfaces, driving temperature rises (Addae & Oppelt, 2019). These patterns highlight urbanization's universal impact on surface temperatures, especially in Sub-Saharan Africa, where urban planning often lags behind development. Sustainable planning and green space integration are crucial to mitigate temperature increases from land-use changes.

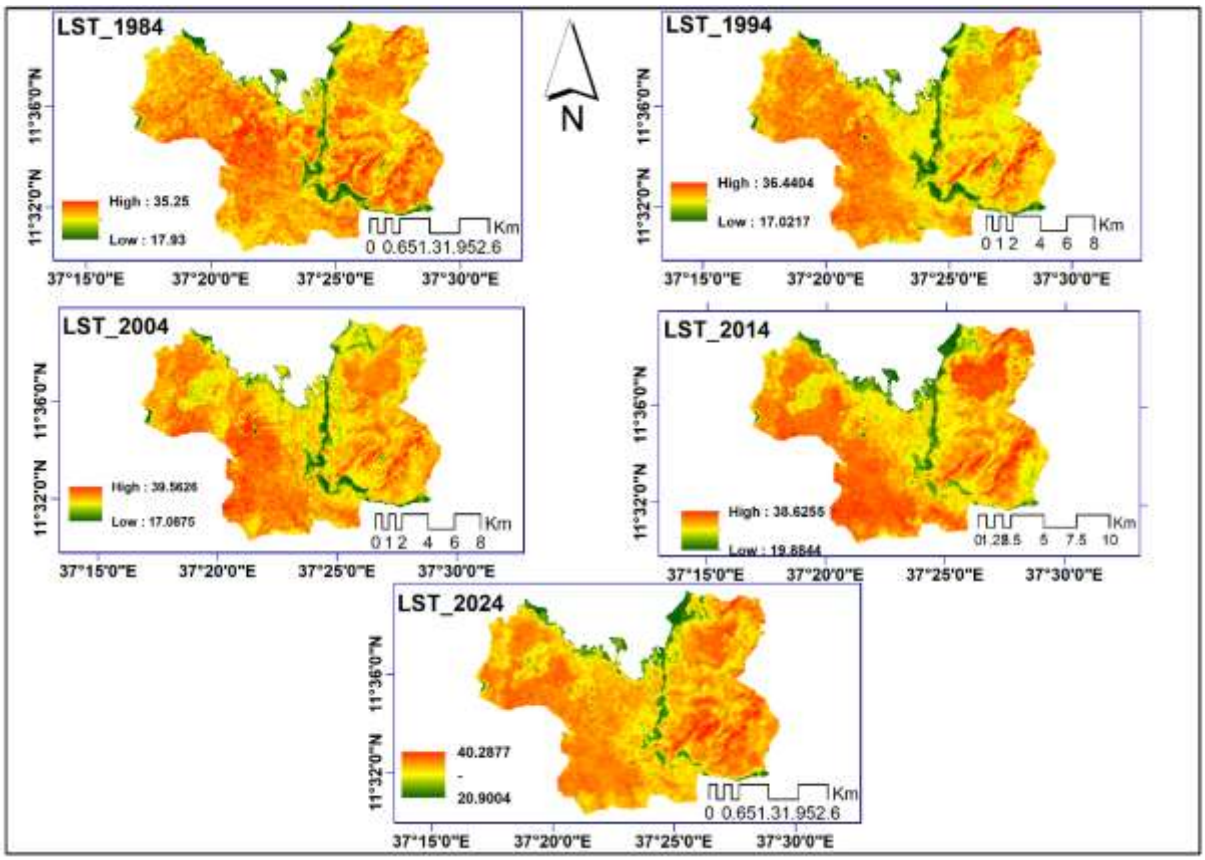


Figure 2.4 LST maps for the years 1984, 1994, 2004, 2014 and 2024 of Bahir Dar city

By 2014, the mean LST increased slightly to 31.87°C, with the maximum temperature decreasing marginally to 38.62°C, likely due to small-scale greening efforts. However, these were insufficient to counteract urban heat effects, as seen in Addis Ababa (Terfa et al., 2020). By 2024, the mean LST decreased to 29.22°C, suggesting urban planning or green space improvements, but the maximum temperature reached 40.28°C, highlighting persistent extreme heat. This mirrors trends in cities like Lagos, where greening alleviated some heat but couldn't reduce peak temperatures due to impervious surfaces (Adelekan, 2020). These findings suggest

that while greening can mitigate average temperatures, the broader challenge of managing extreme urban heat remains.

2.3.2.1. Contrasting pre- and post-capital status periods

The thermal environment of Bahir Dar city changed significantly over 40 years, influenced by urbanization and LST dynamics. During the precapital period (1984–1994), the mean LST rose modestly from 28.22°C to 28.81°C (+0.59°C), reflecting the cooling effects of dominant natural landscapes like agriculture, vegetation, and wetlands. The minimum temperature slightly decreased from 17.93°C to 17.02°C, while the maximum LST increased moderately from 35.25°C to 36.44°C, indicating localized heat intensification. The LST standard deviation grew from 2.55°C to 2.86°C, suggesting increasing thermal variability as urban expansion began affecting land cover.

During the post-capital period (1994–2024), the mean LST rose significantly from 28.81°C to 31.87°C in 2014, before dropping slightly to 29.22°C in 2024, averaging a 0.41°C rise per decade. This increase aligns with built-up areas expanding from 20.97 km² (9.23%) in 1994 to 67.99 km² (29.92%) in 2024. The maximum LST surged to 40.28°C in 2024, driven by impervious surfaces, while the minimum LST fluctuated, peaking at 19.88°C in 2014 and declining to 19.07°C in 2024. Thermal variability (SD) peaked at 3.56°C in 2004 due to rapid land use changes but declined to 3.28°C by 2024, reflecting reduced variability as urbanization homogenized the thermal landscape. The postcapital LST surge aligns with studies in rapidly urbanizing cities like Mekelle, Ethiopia, and Hyderabad, India, where urban growth has driven surface temperature increases due to impervious surfaces and vegetation loss (Suthar et al., 2024; Tesfamariam et al., 2023). This highlights urbanization's role in amplifying the UHI effect, affecting liveability, energy demand, and ecosystems.

The findings highlight the urgent need for climate-sensitive urban planning in Bahir Dar. Strategies such as green infrastructure, wetland restoration, increased vegetation, and energy-efficient building designs can mitigate the UHI effect. As Zhao et al. (2014) suggested, prioritizing green corridors and adaptive measures enhances urban resilience. The slight mean LST decrease from 2014–2024 suggests potential for effective mitigation strategies. These results contribute to understanding urban climate dynamics in Sub-Saharan Africa, where rapid, unplanned urbanization is common (Saghir & Santoro, 2018). Lessons from Bahir Dar stress the importance of balancing urban growth with environmental sustainability, offering insights for other emerging cities.

2.3.2.2. Analysis of LST by land use class (1984–2024)

The LST analysis for Bahir Dar (1984–2024) reveals significant warming, driven by urbanization and land conversion. The UHI effect has intensified as built-up areas expand, degrading natural covers like vegetation, wetlands, and water bodies. Water bodies, typically cooling features, saw LST rise from 19.5°C in 1984 to 22.0°C in 2024 (Table 2.4). This modest but concerning increase reflects urbanization's impact on their microclimate-regulating role. Wetlands in Bahir Dar experienced a 3.5°C LST rise, highlighting their vulnerability to urban pressures. Similar trends globally and in Ethiopian cities like Addis Ababa, Adama, and Hawassa show wetland loss exacerbates the UHI effect, diminishing ecosystem services such as carbon sequestration, water filtration, and biodiversity support (Guto, 2021; Terfa et al., 2019). The warming of wetlands and water bodies underscores the need for urban planning to prioritize their conservation and restoration to mitigate temperature increases.

Table 2.4 Summary of overall LST & LST across LU classes in Bahir Dar city (1984-2024)

Land use classes	LST (°C)																			
	1984				1994				2004				2014				2024			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Overall LST	17.93	35.25	28.22	2.55	17.02	36.44	28.81	2.86	17.08	39.56	31.08	3.56	19.88	38.62	31.87	3.45	19.07	40.28	29.22	3.28
Water body	17.9	24.0	19.5	1.2	17.02	24.5	20.0	1.4	17.08	25.0	20.5	1.5	19.8	26.0	21.0	1.6	19.07	27.0	22.0	1.7
Wetland	20.0	25.0	22.5	1.5	21.0	26.5	23.0	1.6	21.5	28.0	24.0	1.7	22.5	29.0	25.0	1.8	24.0	30.0	26.0	1.9
Vegetation	22.0	28.0	24.8	1.8	23.0	29.5	25.5	1.9	24.0	30.5	26.5	2.0	25.0	31.0	27.0	2.1	26.0	32.0	28.0	2.2
Agricultural land	23.5	30.0	26.5	1.7	24.5	31.0	27.0	1.8	25.5	32.0	28.0	1.9	26.5	33.0	29.0	2.0	27.0	34.0	30.0	2.1
Built-Up	25.0	35.2	29.5	2.1	27.0	36.4	31.5	2.3	29.0	39.5	33.0	2.5	30.0	38.6	34.0	2.6	31.0	40.3	35.5	2.8

The mean LST in vegetated areas rose by 3.2°C from 1984 to 2024, with the sharpest increase after 1994 due to accelerated urbanization and vegetation loss, which reduced cooling from evapotranspiration and shading. Temporary stabilization between 2004 and 2014 likely resulted from localized greening efforts, though insufficient to offset urban sprawl. Agricultural lands also saw a 3.5°C LST rise, driven by peri-urban farmland conversion to built-up areas, intensifying the UHI effect and threatening food security by reducing arable land (Belete, 2022). Built-up areas showed the highest LST values, with a 6°C increase from 1984 to 2024, reaching a maximum of 40.3°C by 2024, highlighting the UHI effect in Bahir Dar (Figure 2.5). Similar global studies link urbanization to rising temperatures due to impervious surfaces like roads and buildings (Chapman et al., 2017; Kowe et al., 2022). The rapid LST rise underscores the need for sustainable urban planning, including green infrastructure, to mitigate the UHI effect and enhance urban livability.

The findings from Bahir Dar align with studies in Shanghai, Beijing, and Addis Ababa, where urbanization has significantly increased LST and exacerbated the UHI effect (Terfa et al., 2019; Wang & Xu, 2021). These trends highlight the need for effective urban governance, with Xueqin et al. (2022) recommending strategies such as integrating green spaces, protecting water bodies, and restoring wetlands to mitigate the UHI effect and enhance climate resilience.

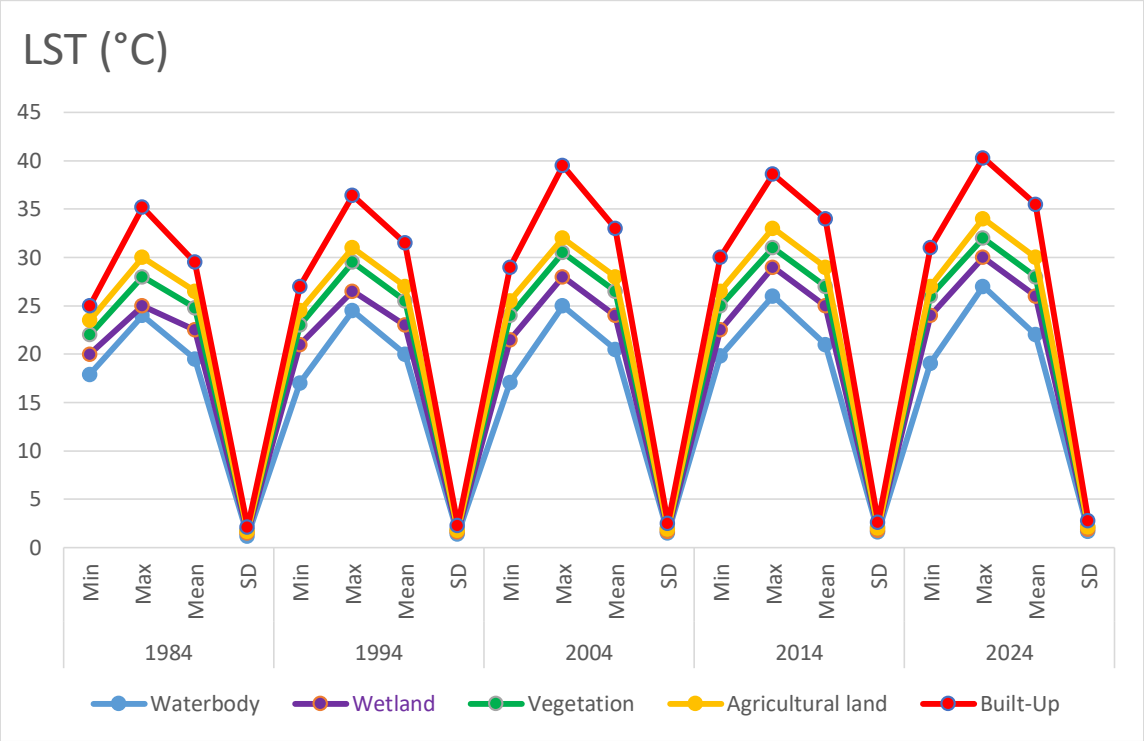


Figure 2.5 LST across land use classes in Bahir Dar city (1984–2024)

2.3.3. LST Changes Associated with Bahir Dar's Capital Status

LST in Bahir Dar city rose significantly between 1984 and 2024, driven by urban expansion following its 1994 designation as a regional capital. From 1994–2024, built-up areas saw a 4.0°C increase in mean LST, exceeding the 2.0°C rise from 1984–1994 (Table 2.5). This warming, linked to impervious surfaces like asphalt and concrete, intensified the UHI effect. Similar trends in cities like New Delhi and Nairobi (Scott et al., 2017; Srivastava & Satyaprakash, 2020) highlight urbanization's role in rising temperatures, emphasizing the impact of urban growth and infrastructure on LST.

Water bodies saw a modest LST rise of +2.5°C (1984–2024), with a notable +1.0°C increase in the last decade (2014–2024) due to encroachment and reduced vegetative buffers (Table 2.5). Similar urbanization impacts were observed in the Yangtze River Delta (Sun et al., 2024). Wetlands experienced a +3.5°C rise, increasing steadily by +1.0°C per decade after 1994, driven by drainage and urban development, reducing their cooling via evapotranspiration. This

mirrors trends in cities like Beijing, where wetland loss intensifies the UHI effect (Tian et al., 2021). Agricultural land showed a +3.5°C rise, with significant warming post-1994, reflecting its conversion to heat-retaining urban areas.

Vegetation areas in Bahir Dar city saw a +3.2°C LST rise (1984–2024), with the sharpest increase between 1994 and 2024, driven by deforestation and urbanization following its 1994 regional capital designation. The loss of vegetation in urban areas has significantly elevated temperatures, a trend also observed in Addis Ababa. Rapid urban growth, particularly at urban fringes, has intensified the UHI effect by reducing vegetation, as noted by Deribew and Dalacho (2019). LST changes before and after Bahir Dar's 1994 capital designation reveal urbanization's impact on its thermal environment. Pre-1994, LST increases were modest, with natural land covers like wetlands and vegetation dominating. Post-1994, rapid urban expansion caused significant LST rises across all land-use categories, especially in built-up areas (see Figure 2.5).

Table 2.5 Mean land surface temperature changes before and after 1994 (°C)

Land use classes	Change in mean LST (◦C)					
	1984–1994	**1994–2004**	**2004–2014**	**2014–2024**	**1994–2024**	**1984–2024**
Water Body	+0.5	+0.5	+0.5	+1.0	+2.0	+2.5
Wetland	+0.5	+1.0	+1.0	+1.0	+3.0	+3.5
Vegetation	+0.7	+1.0	+0.5	+1.0	+2.5	+3.2
Agricultural Land	+0.5	+1.0	+1.0	+1.0	+3.0	+3.5
Built-Up	+2.0	+1.5	+1.0	+1.5	+4.0	+6.0

Bahir Dar's LST changes reveal urban expansion as a key driver of rising temperatures, with built-up areas warming and natural land covers degrading. Similar trends are seen globally and in Ethiopian cities like Addis Ababa and Mekelle, where urban growth has intensified the UHI effect (Duan et al., 2021; Hagos, 2023; Hailu et al., 2024a). Sustainable strategies, such as urban greenery, green roofs, permeable surfaces, and wetland restoration, as in Singapore (Wong et al., 2021), are essential to mitigate warming. Integrating climate adaptation into urban planning is crucial for Bahir Dar’s environmental sustainability and climate resilience.

2.3.4. Land Use Indices

2.3.4.1. Normalized difference vegetation index (NDVI)

The NDVI analysis shows a sharp decline in Bahir Dar's vegetation, particularly after 1994. In 1984, the mean NDVI was 0.16, indicating moderate vegetation (Table 2.6). By 1994, it dropped to 0.14, signaling early urbanization. Between 1994 and 2004, urbanization led to a steep decline to -0.19, with minimal recovery by 2024 (0.19) despite some greening efforts (Figure 2.6). This trend mirrors other cities like Dhaka (Rahman et al., 2022) and Addis Ababa (Moisa & Gemeda, 2021), where urbanization has caused significant vegetation loss, intensifying the UHI effect and threatening climate stability and biodiversity. Pandey, (2024) also indicated LST and its influential factors are dynamically changing within Imphal which sterengthens the current results.

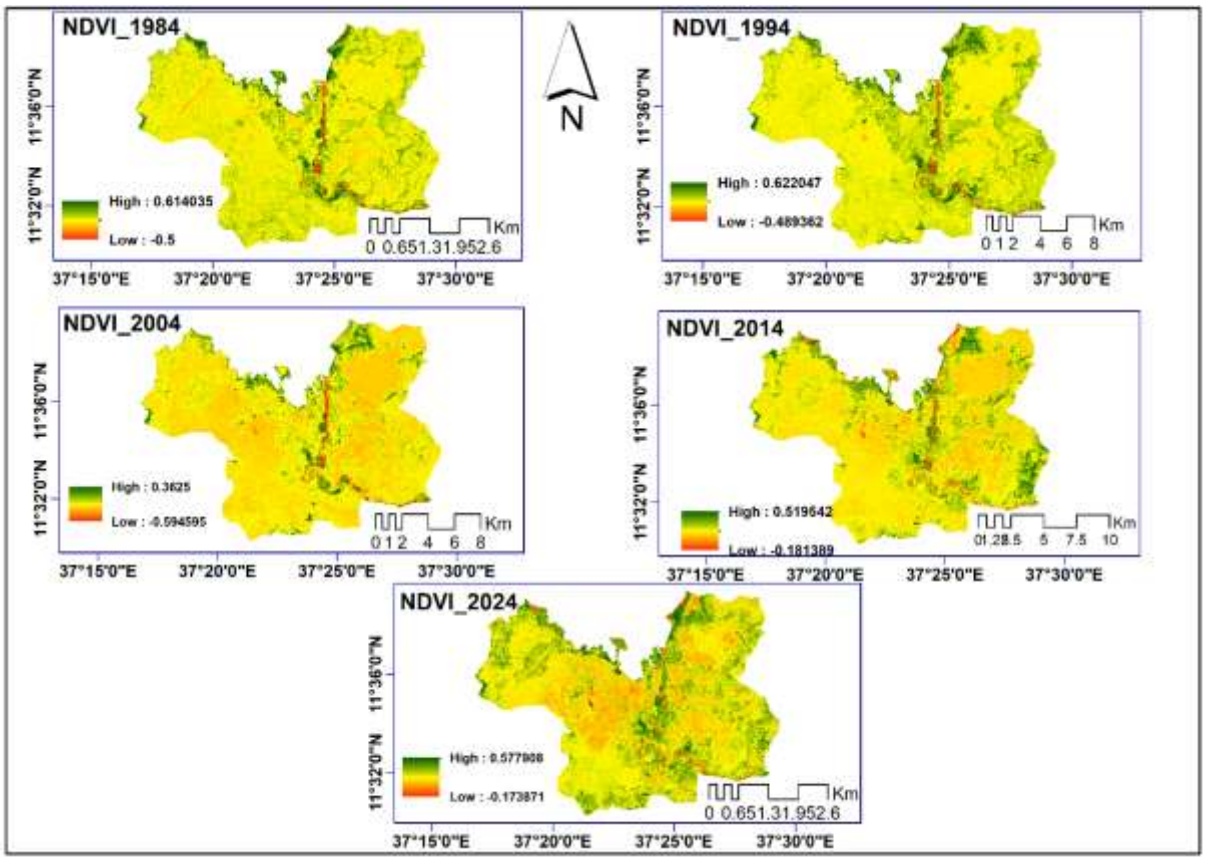


Figure 2.6 NDVI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024

The minimal increase in the NDVI values in 2014 and 2024 suggests the potential for urban greening initiatives to mitigate some environmental damage. However, the results highlight the need for comprehensive vegetation conservation strategies to preserve the ecological benefits of green spaces in continued urban growth.

2.3.4.2. Normalized difference built-up index (NDBI)

NDBI values show consistent growth in Bahir Dar's built-up areas, especially after 1994. In 1984, the mean NDBI was -0.10, rising to -0.03 in 1994 (Table 2.6) as urbanization began. By 2004, the mean reached 0.19, signaling rapid expansion, and by 2024, it stabilized at 0.28, indicating that built-up areas were nearing capacity (Figure 2.7). This pattern mirrors global trends like in Cairo (Salem & Tsurusaki, 2024), where urbanization converted agricultural land, increasing NDBI values. The growth of impervious surfaces in Bahir Dar has worsened the UHI effect and reduced groundwater recharge (Youssef et al., 2020). The 2024 NDBI stabilization suggests a potential limit to urban development, reflecting challenges in managing population growth and infrastructure.

Table 2.6 Summary of LU indices in Bahir Dar city for the years 1984, 1994, 2004, 2014 and 2024

YEAR	NDVI				NDBI				MNDWI			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
1984	-0.5	0.61	0.16	0.1	-0.41	0.27	-0.1	0.07	-0.64	0.63	-0.40	0.12
1994	-0.49	0.62	0.14	0.1	-0.45	0.46	-0.03	0.07	-0.65	0.67	-0.45	0.11
2004	-0.63	0.43	-0.19	0.1	-0.73	0.56	0.19	0.09	-0.49	0.71	-0.18	0.11
2014	-0.18	0.52	0.16	0.07	-0.63	0.60	0.26	0.08	-0.37	0.32	-0.18	0.07
2024	-0.17	0.58	0.19	0.08	-0.71	0.60	0.28	0.09	-0.59	0.31	-0.17	0.07

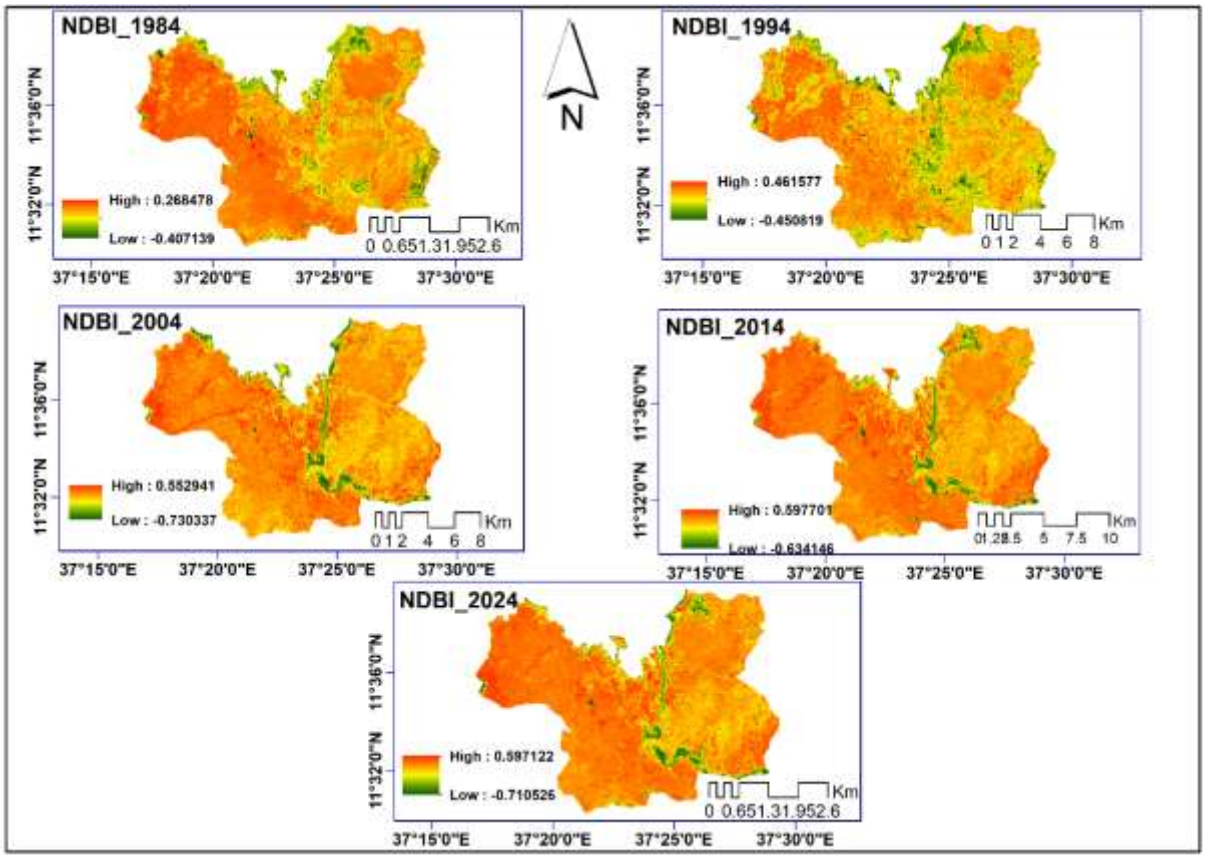


Figure 2.7 NDBI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024

2.3.4.3. Modified normalized difference water index (MNDWI)

MNDWI values reveal the shrinking visibility of water and wetlands due to urbanization. In 1984, the mean MNDWI was -0.40, indicating well-preserved water resources. By 1994, it declined to -0.45 as urban encroachment began (Figure 2.8). A temporary rise between 2004 and 2014 may reflect seasonal factors or improved water management. By 2024, the MNDWI slightly improved to -0.17, showing ongoing reductions in water and wetland areas as urbanization progressed. The decline in MNDWI mirrors global trends, where urbanization depletes water resources. In cities like Mumbai and Beijing, urban growth has reduced water bodies' size and quality (Shiva Shankar et al., 2021; Zhang et al., 2017). Similarly, in Addis Ababa, urbanization has degraded wetlands and water bodies (Hailu et al., 2024b). In Bahir Dar, this decline threatens biodiversity and exacerbates the UHI effect.

Bahir Dar's designation as the regional capital in 1994 accelerated urbanization, causing significant declines in vegetation, wetlands, and water resources, as shown by NDVI, NDBI, and MNDWI trends (Figures 5.5-5.7). This pattern aligns with global examples where capital city status drives urban growth and environmental degradation (Wayne et al., 2020). However, cities like Curitiba, Brazil, demonstrate that robust urban planning with green spaces and water

management can ensure sustainable growth (Zingoni de Baro, 2022). Bahir Dar could adopt similar strategies to balance development and environmental preservation.

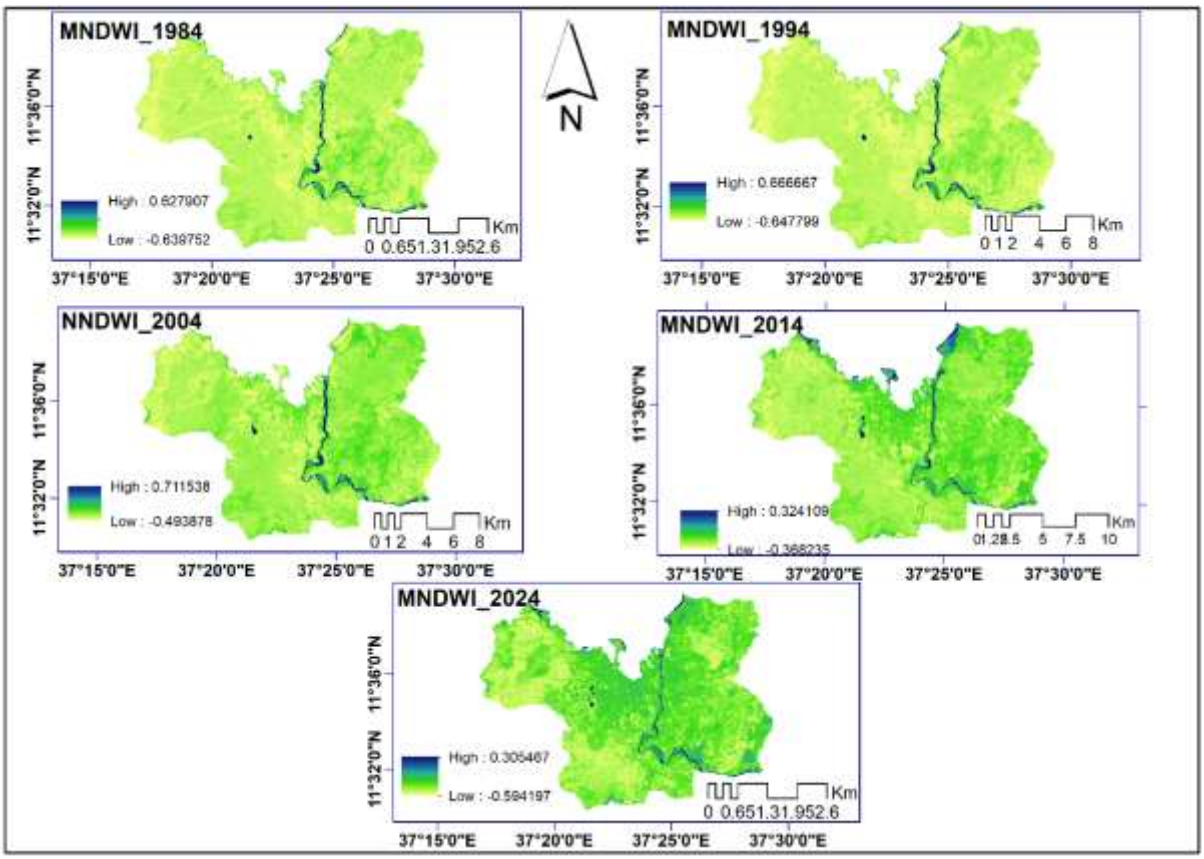


Figure 2.8 MNDWI maps of Bahir Dar city for 1984, 1994, 2004, 2014 and 2024

2.3.5. Correlation between LST and land use indices

The analysis of LST and land use indices (NDVI, NDBI, MNDWI) reveals urbanization's thermal impacts on Bahir Dar. The strong negative correlation between LST and NDVI in 1984 (slope = -0.069, R^2 = 0.9902) (Figure 2.9), highlights vegetation's cooling role. As urbanization intensified, this effect weakened, with slopes of -0.0448 (2014) and -0.0549 (2024), reflecting green space loss. Similar trends were observed in Beijing (Wang & Xu, 2021) and Addis Ababa (Deribew & Dalacho, 2019). These findings stress the need for urban planning that prioritizes green infrastructure to counteract the UHI effect.

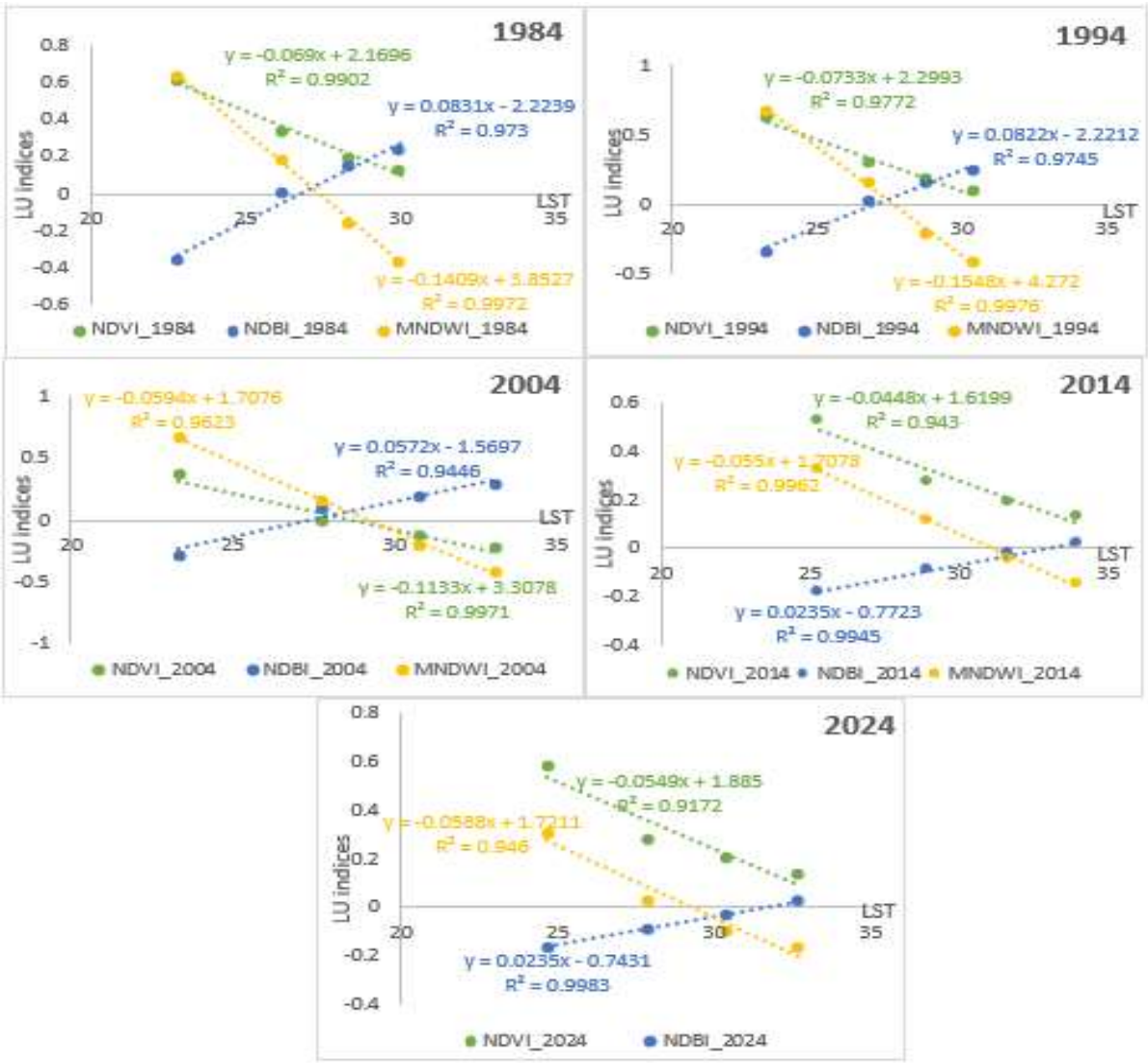


Figure 2.9 Correlations between LST and land use indices

The positive correlation between LST and NDBI highlights built-up areas' role in intensifying urban heat. In 1984, the correlation (slope = 0.0831, R^2 = 0.973) reflected the early impact of impervious surfaces, which grew significantly by 2024 (slope = 0.0235, R^2 = 0.9983) due to rapid urbanization after Bahir Dar became a regional capital in 1994. Similar trends are observed in Bangalore, India (Sussman et al., 2019). This underscores the need for climate-responsive urban planning, including green roofs, urban parks, and reduced impervious surfaces to mitigate the UHI effect.

The analysis revealed a negative correlation between LST and MNDWI, highlighting the cooling effects of water bodies and wetlands. In 1984, the strong correlation (slope = -0.1409, R^2 = 0.9972) emphasized water resources' role in temperature regulation, but by 2024, this had weakened (slope = -0.0588, R^2 = 0.946) due to urban encroachment. Similar trends in Cairo

(Abutaleb et al., 2019), and Jimma (Berkessa et al., 2023) show wetland loss exacerbating the UHI effect.

This study underscores how urbanization has weakened the cooling effects of vegetation, wetlands, and water bodies while increasing LST through built-up areas. Similar global trends in Delhi (Srivastava & Satyaprakash, 2020) and Lagos (Jiang et al., 2021) highlight the need for green spaces, water conservation, and sustainable infrastructure in urban planning. For Bahir Dar, policy actions like reforestation, wetland conservation, and climate-sensitive designs are essential to address thermal challenges from rapid urban growth.

2.4. Conclusion

This study analyzed the impacts of LULC changes on LST in Bahir Dar over 40 years focusing on its designation as a regional capital in 1994. Rapid urbanization and population growth have driven significant LULC changes, resulting in environmental and thermal impacts. Built-up areas expanded by 366%, from 14.60 km² to 67.99 km², at the cost of agricultural land (-43.79 km²), vegetation (-4.28 km²), and wetlands (-4.37 km²). This land conversion intensified the UHI effect, with built-up areas experiencing a 6.0°C increase in mean LST, while the loss of vegetation, wetlands, and water bodies reduced their cooling capacity.

Before 1994, Bahir Dar's stable thermal conditions were supported by natural land cover. Post-1994, rapid urbanization led to significant LST increases and the expansion of high-LST zones, underscoring the thermal consequences of urban growth. Negative correlations between LST and NDVI/MNDWI reaffirm the cooling effects of vegetation and water, while the positive correlation with NDBI highlights built-up areas as key contributors to surface warming.

The study underscores the urgent need for sustainable urban planning. Strategies such as reforestation, wetland conservation, urban greening (e.g., tree planting, green roofs), and the use of permeable surfaces can mitigate urban heat while supporting biodiversity. Policies to protect agricultural land and balance development with ecological sustainability are also crucial. Generally, Bahir Dar's urbanization has drastically altered its LULC and thermal landscape. Policymakers must prioritize sustainable, climate-resilient planning to mitigate urban heat, enhance liveability, and build a sustainable future.

2.4.1. Limitations and Future Directions

This study provides valuable insights into the long-term impacts of LULC changes on LST in Bahir Dar City. However, some limitations should be acknowledged. The study does not fully

account for socio-economic factors, such as population density and energy consumption, which can influence urban heat dynamics. Future research should incorporate climate modeling and socio-economic data to provide a more comprehensive understanding of the drivers of urban heat. Comparative studies across multiple cities can also help generalize the findings and offer broader policy recommendations for climate-resilient urban planning.

REFRENCES

Abutaleb, K., Ngie, A., Darwish, A., Ahmed, M., Arafat, S., Ahmed, F., Abutaleb, K., Ngie, A., Darwish, A., Ahmed, M., Arafat, S., & Ahmed, F. (2019). Assessment of Urban Heat Island Using Remotely Sensed Imagery over Greater Cairo, Egypt. *Advances in Remote Sensing*, *4*(1), 35–47. https://doi.org/10.4236/ARS.2015.41004

Addae, B., & Oppelt, N. (2019). Land-Use/Land-Cover Change Analysis and Urban Growth Modelling in the Greater Accra Metropolitan Area (GAMA), Ghana. *Urban Science*, *3*(1). https://doi.org/10.3390/urbansci3010026

Adegun, O. B. (2017). Green infrastructure in relation to informal urban settlements. *Journal of Architecture and Urbanism*, *41*(1), 22–33. https://doi.org/10.3846/20297955.2017.1296791

Adelekan, I. O. (2020). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment and Urbanization*, *22*(2), 433–450. https://doi.org/10.1177/0956247810380141

Alemayehu, Z. Y., Minale, A. S., & Legesse, S. A. (2023). Land-use and land-cover dynamics nexus to local climate variability in Suha watershed, upper Blue Nile basin, Northwest Ethiopia. *Sustainable Environment*, *9*(1). https://doi.org/10.1080/27658511.2023.2278828

Alves, E. D. L., & Lopes, A. (2017). The Urban Heat Island Effect and the Role of Vegetation to Address the Negative Impacts of Local Climate Changes in a Small Brazilian City. *Atmosphere 2017, Vol. 8, Page 18*, *8*(2), 18. https://doi.org/10.3390/ATMOS8020018

Appelhans, N. (2017). Urban Planning and Everyday Urbanisation A Case Study on Bahir Dar, Ethiopia. In *Dissertation*. https://doi.org/10.1515/9783839437155

Arulbalaji, P., & Gurugnanam, B. (2014). Evaluating the normalized difference vegetation index using landsat data by ENVI in salem district, Tamilnadu, India. *International Journal of Development Research*, *4*(9), 1844–1846.

Assefa, W. W., Eneyew, B. G., & Wondie, A. (2022). The driving forces of wetland degradation in Bure and Wonberma Woredas, Upper Blue Nile basin, Ethiopia. *Environmental Monitoring and Assessment*, *194*(11), 1–26. https://doi.org/10.1007/S10661-022-10516-8/TABLES/3

Bahir Dar City Structural Plan Preparation Project Office. (2020). *Population Study Report*.

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

Balew, A., & Semaw, F. (2022). Impacts of land-use and land-cover changes on surface urban heat islands in Addis Ababa city and its surrounding. *Environment, Development and Sustainability*, *24*(1), 832–866. https://doi.org/10.1007/s10668-021-01472-3

Belete, B. (2022). Urbanization and Its Effect on Farmer‟s Livelihoods: An assessment of Adama City Peri- Urban Areas, Ethiopia. In *Dissertation*. Ethiopian Civil Service University School.

Berkessa, Y. W., Bulto, T. W., Moisa, M. B., Gurmessa, M. M., Werku, B. C., Juta, G. Y., Negash, D. A., & Gemeda, D. O. (2023). Impacts of urban land use and land cover change on wetland dynamics in Jimma city, southwestern Ethiopia. *Journal of Water and Climate Change*, *14*(7), 2397–2415. https://doi.org/10.2166/wcc.2023.102

Birhanu, B., Kebede, S., Zeleke, G., & Charles, K. (2023). *Addis Ababa's water crisis: challenges and opportunities*. https://doi.org/10.5287/ORA-2RKEZ0NME

Brenner, N. (2013). Theses on Urbanization. *Public Culture*, *25*(1 (69)), 85–114. https://doi.org/10.1215/08992363-1890477

Chander, G., Markham, B. L., & Helder, D. L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. *Remote Sensing of Environment*, *113*(5), 893–903. https://doi.org/10.1016/j.rse.2009.01.007

Chapman, S., Watson, J. E. M., Salazar, A., Thatcher, M., & McAlpine, C. A. (2017). The impact of urbanization and climate change on urban temperatures: a systematic review. *Landscape Ecology*, *32*(10), 1921–1935. https://doi.org/10.1007/s10980-017-0561-4

Corbella, O. D., Silva Barbosa, G., & Drach, P. R. C. (2011). Sustainable Parameters for Latin American Cities. *Proceedings of the World Renewable Energy Congress – Sweden, 8–13 May, 2011, Linköping, Sweden*, *57*(January), 3058–3065. https://doi.org/10.3384/ecp110573058

CSA. (1984). The 1984 Population and Housing Census of Ethiopia. In *Central Statistical Authority* (Issue December). http://www.csa.gov.et/surveys/Population and Housing census/ETH-pop-2007/survey0/data/Doc/Reports/National_Statistical.pdf

CSA. (1995). Transitional Government of Ethiopia Office of the Population and Housing Census Commission the 1994 Population and Housing Census of Ethiopia Analytical Report At Addis Ababa Level.Volume 1 Statistical Report. *Central Statistical Authority*.

CSA. (2018). Statistical report on the 2018 urban Employment Unemployment survey. *Central Statistical Agency, Ethiopia, October*, 301.

Debebe, F. A., & Miteku, M. N. (2023). Effects of land use/land cover Changes on land surface Temperature and Agricultural lands in Bahir Dar Zuria Woreda. *Journal of Urban Development Studies*, *3*(1).

Dekolo, S., Oduwaye, L., & Nwokoro, I. (2015). Urban sprawl and loss of agricultural land in peri-urban areas of Lagos. *Regional Statistics*, *5*(2), 20–33. https://doi.org/10.15196/RS05202

Deribew, K. T., & Dalacho, D. W. (2019). Land use and forest cover dynamics in the North-eastern Addis Ababa, central highlands of Ethiopia. *Environmental Systems Research*, *8*(1), 1–18. https://doi.org/10.1186/S40068-019-0137-1/FIGURES/8

Dibaba, W. T. (2023). Urbanization-induced land use/land cover change and its impact on

surface temperature and heat fluxes over two major cities in Western Ethiopia. *Environmental Monitoring and Assessment*, *195*(9). https://doi.org/10.1007/s10661-023-11698-5

Din, S. U., & Mak, H. W. L. (2021). Retrieval of land-use/land cover change (Lucc) maps and urban expansion dynamics of hyderabad, pakistan via landsat datasets and support vector machine framework. *Remote Sensing*, *13*(16), 1–25. https://doi.org/10.3390/rs13163337

Dodman, D., Hayward, B., Pelling, M., Broto, V. C., & Chow, W. T. L. (2022). *Cities, settlements and key infrastructure*. 907–1040.

Duan, Y., Tang, J., Li, Z., Yang, B., Yan, Y., & Yang, Y. (2021). Vegetated buffer zone restoration planning in small urban watersheds. *Water (Switzerland)*, *13*(21). https://doi.org/10.3390/w13213000

Eshetie, S. M. (2024). Exploring urban land surface temperature using spatial modelling techniques : a case study of Addis Ababa city , Ethiopia. *Scientific Reports*, 1–16. https://doi.org/10.1038/s41598-024-55121-6

Ethiopia Peace Observatory. (2024, August 8). *Central Ethiopia/Regional Profile*. https://epo.acleddata.com/central-ethiopia/

Fan, C., & Wang, Z. (2020). Spatiotemporal characterization of land cover impacts on urban warming: A spatial autocorrelation approach. *Remote Sensing*, *12*(10). https://doi.org/10.3390/rs12101631

Fitawok, M. B., Derudder, B., Minale, A. S., Passel, S. Van, Adgo, E., & Nyssen, J. (2020). Modeling the impact of urbanization on land-use change in Bahir Dar City, Ethiopia: An integrated cellular automata-markov chain approach. *Land*, *9*(4), 1–17. https://doi.org/10.3390/land9040115

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder, P. K. (2005). Global consequences of land use. *Science*, *309*(5734), 570–574. https://doi.org/10.1126/SCIENCE.1111772/SUPPL_FILE/FOLEY_SOM.PDF

Foody, G. M. (2020). Explaining the unsuitability of the kappa coefficient in the assessment and comparison of the accuracy of thematic maps obtained by image classification. *Remote Sensing of Environment*, *239*, 111630. https://doi.org/10.1016/J.RSE.2019.111630

Gazi, M. Y., Rahman, M. Z., Uddin, M. M., & Rahman, F. M. A. (2021). Spatio-temporal dynamic land cover changes and their impacts on the urban thermal environment in the Chittagong metropolitan area, Bangladesh. *GeoJournal*, *86*(5), 2119–2134. https://doi.org/10.1007/s10708-020-10178-4

Getu, K., & Bhat, H. G. (2024). Quantifying Spatio-temporal dynamics of land surface temperature for the rapidly growing city of Bahir Dar, Northwest Ethiopia using multidated Landsat data. *Physics and Chemistry of the Earth*, *134*(August 2022), 103543. https://doi.org/10.1016/j.pce.2024.103543

Guto, N. S. (2021). *Impact of Residential Development on Urban Wetlands: The Case of Watiti Wetland, Kangemi Estate, Nairobi County.* | *Afribary* [KENYATTA

UNIVERSITY]. https://afribary.com/works/impact-of-residential-development-on-urban-wetlands-the-case-of-watiti-wetland-kangemi-estate-nairobi-county

Hagos, F. (2023). Spatio- Temporal Technology Analysis for Urban Land Use Growth In The Case Of Mekelle City, Tigray, Northern Ethiopia. *International Journal of Geo Science and Remote Sensing*, *2*(1). https://doi.org/10.36266/IJGRS/108

Hailu, T., Assefa, E., & Zeleke, T. (2024a). Land use transformation by urban informal settlements and ecosystem impact. *Environmental Systems Research*, *13*(1), 1–24. https://doi.org/10.1186/S40068-024-00359-2/TABLES/11

Hailu, T., Assefa, E., & Zeleke, T. (2024b). Urban expansion induced land use changes and its effect on ecosystem services in Addis Ababa, Ethiopia. *Frontiers in Environmental Science*, *12*, 1454556. https://doi.org/10.3389/FENVS.2024.1454556

Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia. *Landscape and Urban Planning*, *106*(2), 149–157. https://doi.org/10.1016/j.landurbplan.2012.02.016

Hassan, T., Zhang, J., Prodhan, F. A., Pangali Sharma, T. P., & Bashir, B. (2021). Surface Urban Heat Islands Dynamics in Response to LULC and Vegetation across South Asia (2000–2019). *Remote Sensing*, *MDPI*, *13*(16), 3177. https://doi.org/10.3390/RS13163177

Ibrahim, H., Salama, A., Wiedmann, F., Aboukalloub, B., & Awwaad, R. (2020). Investigating land use dynamics in emerging cities: the case of downtown neighbourhood in Doha. *Journal of Urban Design*, *25*(3), 387–411. https://doi.org/10.1080/13574809.2019.1632179

Isioye, O. A., Ikwueze, H. U., & Akomolafe, E. A. (2020). Urban Heat Island Effects and Thermal Comfort in Abuja Municipal Area Council of Nigeria. *FUTY Journal of the Environment*, *14*(2), 19–34. https://www.ajol.info/index.php/fje/article/view/201398

Jiang, S., Zhang, Z., Ren, H., Wei, G., Xu, M., & Liu, B. (2021). Spatiotemporal Characteristics of Urban Land Expansion and Population Growth in Africa from 2001 to 2019: Evidence from Population Density Data. *ISPRS International Journal of Geo-Information 2021, Vol. 10, Page 584*, *10*(9), 584. https://doi.org/10.3390/IJGI10090584

Kindu, M., Angelova, D., Schneider, T., Döllerer, M., Teketay, D., & Knoke, T. (2020). Monitoring of Urban Growth Patterns in Rapidly Growing Bahir Dar City of Northwest Ethiopia with 30 year Landsat Imagery Record. *ISPRS International Journal of Geo-Information*, *9*(9), 548. https://doi.org/10.3390/IJGI9090548

Kowe, P., Dube, T., Mushore, T. D., Ncube, A., Nyenda, T., Mutowo, G., Chinembiri, T. S., Traore, M., & Kizilirmak, G. (2022). Impacts of the spatial configuration of built-up areas and urban vegetation on land surface temperature using spectral and local spatial autocorrelation indices. *Remote Sensing Letters*, *13*(12), 1222–1235. https://doi.org/10.1080/2150704X.2022.2142073

Levin, N. (2000). Fundamentals of Remote Sensing. In N. Levin (Ed.), *1st Hydrographic Data Management course, IMO - International Maritime Academy* (Issue November). https://doi.org/10.1007/978-3-642-34085-7_7

Mekonnen, G. T., Berlie, A. B., Legesse, S. A., & Wubie, M. A. (2023). The implication of climate change in causing urban heat island in Gondar City, Ethiopia: an analysis made using Mann–Kendall's trend test and homogeneity test. *Arabian Journal of Geosciences*, *16*(12). https://doi.org/10.1007/s12517-023-11739-w

Meng, Q., Liu, W., Zhang, L., Allam, M., Bi, Y., Hu, X., Gao, J., Hu, D., & Jancsó, T. (2022). Relationships between Land Surface Temperatures and Neighboring Environment in Highly Urbanized Areas: Seasonal and Scale Effects Analyses of Beijing, China. *Remote Sensing 2022, Vol. 14, Page 4340*, *14*(17), 4340. https://doi.org/10.3390/RS14174340

Miringay, J., Burra, M. M., & Babere, N. J. (2024). Urban territorial regionalisation and the emergence of urban villagization localities of Dodoma, the National Capital City of Tanzania. *Journal of Geography and Regional Planning*, *17*(December), 78–95. https://doi.org/10.5897/JGRP2024.0871

Mohiuddin, G., & Mund, J.-P. (2024). Spatiotemporal Analysis of Land Surface Temperature in Response to Land Use and Land Cover Changes : A Remote Sensing Approach. *Remote Sensing Article*.

Moisa, M. B., Dejene, I. N., & Gemeda, D. O. (2022). Integration of geospatial technologies with multiple regression model for urban land use land cover change analysis and its impact on land surface temperature in Jimma City, southwestern Ethiopia. *Applied Geomatics*, *14*(4), 653–667. https://doi.org/10.1007/s12518-022-00463-x

Moisa, M. B., & Gemeda, D. O. (2021). Analysis of urban expansion and land use/land cover changes using geospatial techniques: a case of Addis Ababa City, Ethiopia. *Applied Geomatics*, *13*(4), 853–861. https://doi.org/10.1007/S12518-021-00397-W/FIGURES/5

Molla, M. B., Gelebo, G., & Girma, G. (2024). Urban expansion and agricultural land loss: a GIS-Based analysis and policy implications in Hawassa city, Ethiopia. *Frontiers in Environmental Science*, *12*(November), 1499804. https://doi.org/10.3389/FENVS.2024.1499804

Nato, J., Njogu, H., Ngugi, R., Ordu, A. U., & Ijjasz-Vasquez, E. (2023). *Urban economic development in Africa: A case study of Nairobi city*. Brookings. https://www.brookings.edu/articles/urban-economic-development-in-africa-a-case-study-of-nairobi-city/

Nega, W., & Balew, A. (2022). The relationship between land use land cover and land surface temperature using remote sensing: systematic reviews of studies globally over the past 5 years. *Environmental Science and Pollution Research*, *29*(28), 42493–42508. https://doi.org/10.1007/s11356-022-19997-z

Pandey, A., Mondal, A., & Guha, S. (2024). Assess the relationship of land surface temperature with nine land surface indices in a northeast Indian city using summer and winter Landsat 8 data. *Cogent Engineering*, *11*(1). https://doi.org/10.1080/23311916.2024.2382885

Pandey, A., Mondal, A., Guha, S., Upadhyay, P. K., Rashmi, & Kundu, S. (2024). Comparing the seasonal relationship of land surface temperature with vegetation indices and other land surface indices. *Geology, Ecology, and Landscapes*, *00*(00), 1–17. https://doi.org/10.1080/24749508.2024.2392391

Qin, Z., Karnieli, A., & Berliner, P. (2001). A mono-window algorithm for retrieving land

surface temperature from Landsat TM data and its application to the Israel-Egypt border region. *International Journal of Remote Sensing*, *22*(18), 3719–3746. https://doi.org/10.1080/01431160010006971

Rabinovitch, J. (1992). Curitiba: towards sustainable urban development. *Environmrnt and Urbanization*, *4*(2).

Rahman, M. N., Rony, M. R. H., Jannat, F. A., Pal, S. C., Islam, M. S., Alam, E., & Islam, A. R. M. T. (2022). Impact of Urbanization on Urban Heat Island Intensity in Major Districts of Bangladesh Using Remote Sensing and Geo-Spatial Tools. *Climate*, *10*(1). https://doi.org/10.3390/cli10010003

Richmond, A., Myers, I., & Namuli, H. (2018). Urban Informality and Vulnerability - A Case Study in Kampala, Uganda.pdf. *Urban Science*, *2*(22). https://doi.org/10.3390/urbansci2010022

Safari, A., Safari, B., Gasore, J., Kipkoech, B., & Ndakize, J. (2024). Assessing the impact of Land Use Land Cover changes on land surface temperature over Kigali, Rwanda in the past three decades. *Environmental and Sustainability Indicators Journal*, *23*(100452). https://doi.org/10.1016/j.indic.2024.100452

Saghir, J., & Santoro, J. (2018). Urbanization in Sub-Saharan Africa Meeting Challenges by Bridging Stakeholders. *Center For Strategic & International Studies, April*.

Saleem, H., Ahmed, R., Mushtaq, S., Saleem, S., & Rajesh, M. (2024). Remote sensing-based analysis of land use, land cover, and land surface temperature changes in Jammu District, India. *International Journal of River Basin Management*. https://doi.org/10.1080/15715124.2024.2327493

Salem, M., & Tsurusaki, N. (2024). Impacts of Rapid Urban Expansion on Peri-Urban Landscapes in the Global South: Insights from Landscape Metrics in Greater Cairo. *Sustainability 2024, Vol. 16, Page 2316*, *16*(6), 2316. https://doi.org/10.3390/SU16062316

Scott, A. A., Misiani, H., Okoth, J., Jordan, A., Gohlke, J., Ouma, G., Arrighi, J., Zaitchik, B. F., Jjemba, E., Verjee, S., & Waugh, D. W. (2017). Temperature and heat in informal settlements in Nairobi. *PLOS ONE*, *12*(11), e0187300. https://doi.org/10.1371/JOURNAL.PONE.0187300

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(40), 16083–16088. https://doi.org/10.1073/PNAS.1211658109/SUPPL_FILE/PNAS.201211658SI.PDF

Seyoum, S. (2014). The Growth of Bahir Dar: 1941-1974. *Ethiopian Journal of Development Research*, *36*(2), 83–109.

Shiva Shankar, Y., Kumar, A., & Mohan, D. (2021). Climate Change and Water Resources: Emerging Challenges, Vulnerability and Adaptation in Indian Scenario. *Climate Change Impacts on Water Resources*, 365–376. https://doi.org/10.1007/978-3-030-64202-0_32

Shreevastava, A., Bhalachandran, S., McGrath, G. S., Huber, M., & Rao, P. S. C. (2019). Paradoxical impact of sprawling intra-Urban Heat Islets: Reducing mean surface temperatures while enhancing local extremes. *Scientific Reports 2019 9:1*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-56091-w

Simwanda, M., Ranagalage, M., Estoque, R. C., & Murayama, Y. (2019). Spatial analysis of surface urban heat Islands in four rapidly growing african cities. *Remote Sensing*, *11*(14). https://doi.org/10.3390/RS11141645

Srivastava, M. R., & Satyaprakash, N. A. (2020). Urban heat island effect over Delhi NCR using LANDSAT^{TM} data. *International Journal of Global Warming*, *22*(3), 272. https://doi.org/10.1504/IJGW.2020.110865

Stave, K., Goshu, G., & Aynalem, S. (Eds.). (2017). Social and Ecological System Dynamics Characteristics , Trends , and Integration. Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia. *AESS Interdisciplinary Environmental Studies and Sciences Series*, *December*. https://doi.org/10.1007/978-3-319-45755-0

Sun, J., Li, H., Xiao, R., Yao, G., & Zou, F. (2024). Dynamics of Heat Island Intensity in a Rapidly Urbanizing Area and the Cooling Effect of Ecological Land: A Case Study in Suzhou, Yangtze River Delta. *Sustainability 2024, Vol. 16, Page 4422*, *16*(11), 4422. https://doi.org/10.3390/SU16114422

Sussman, H. S., Raghavendra, A., & Zhou, L. (2019). Impacts of increased urbanization on surface temperature, vegetation, and aerosols over Bengaluru, India. *Remote Sensing Applications: Society and Environment*, *16*, 100261. https://doi.org/10.1016/J.RSASE.2019.100261

Suthar, G., Singh, S., Kaul, N., & Khandelwal, S. (2024). Prediction of land surface temperature using spectral indices, air pollutants, and urbanization parameters for Hyderabad city of India using six machine learning approaches. *Remote Sensing Applications: Society and Environment*, *35*, 101265. https://doi.org/10.1016/J.RSASE.2024.101265

Terfa, B. K., Chen, N., Liu, D., Zhang, X., & Niyogi, D. (2019). Urban Expansion in Ethiopia from 1987 to 2017: Characteristics, Spatial Patterns, and Driving Forces. *Sustainability 2019, Vol. 11, Page 2973*, *11*(10), 2973. https://doi.org/10.3390/SU11102973

Terfa, B. K., Chen, N., Zhang, X., & Niyogi, D. (2020). Spatial configuration and extent explains the urban heat mitigation potential due to green spaces: Analysis over Addis Ababa, Ethiopia. *Remote Sensing*, *12*(18), 1–24. https://doi.org/10.3390/RS12182876

Tesfamariam, S., Govindu, V., & Uncha, A. (2023). Spatio-temporal analysis of urban heat island (UHI) and its effect on urban ecology: The case of Mekelle city, Northern Ethiopia. *Heliyon*, *9*(2). https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e13098

Teshome, Z. T., Ayele, Z. T., & Abib, M. I. (2022). Assessment of solid waste management practices in Kebridehar city Somali regional state, Ethiopia. *Heliyon*, *8*(9). https://doi.org/10.1016/j.heliyon.2022.e10451

Tessema, M. W. (2017). Impact of Urban Expansion on Surrounding Peasant Land the Case of Boloso Sore Woreda, Areka Town, SNNPR, Ethiopia. *Global Journal of Human-Social Science*, *17*(2), 1–15.

Tian, L., Li, Y., Lu, J., & Wang, J. (2021). Review on Urban Heat Island in China: Methods, Its Impact on Buildings Energy Demand and Mitigation Strategies. *Sustainability 2021, Vol. 13, Page 762*, *13*(2), 762. https://doi.org/10.3390/SU13020762

UNECA. (2018). World Urbanization Prospects 2018 Highlights. *Department of Economic and Social Affairs*.

UNESCO. (2015). Unlocking the Potential of Urban Communities. Case Studies of Twelve Learning Cities. In *National Institute for Lifelong*. https://files.eric.ed.gov/fulltext/ED564060.pdf

United Nations Economic Commission for Africa (UNECA). (2022). SDG Indicators. In *Department of Economic and Social Affairs*. https://unstats.un.org/sdgs/report/2022/goal-11/

Wang, M., & Xu, H. (2021). The impact of building height on urban thermal environment in summer: A case study of Chinese megacities. *PLOS ONE*, *16*(4), e0247786. https://doi.org/10.1371/JOURNAL.PONE.0247786

Wayne, Z., Robert Northrop, & Michael Andreu. (2020). Enhanced Urban Development and Environmental DegradationReader. *Ecology, Sustainability and Solutions*. doi: 10.1093/acrefore/9780199389414.013.97

Wong, N. H., Tan, C. L., Kolokotsa, D. D., & Takebayashi, H. (2021). Greenery as a mitigation and adaptation strategy to urban heat. *Nature Reviews Earth & Environment 2021 2:3*, *2*(3), 166–181. https://doi.org/10.1038/s43017-020-00129-5

World Bank. (2015). Ethiopia Urbanization Review: Urbanization Institutions for aMiddle-Income Etiopia. *The World Bank Group*.

World Data Atlas. (2022). *Ethiopia Urban population, 1960-2022*. Knoema. https://knoema.com/atlas/Ethiopia/Urban-population

Worseme, H. I. (2004). *Economic analysis of land use: the case of East Hararghe administrative zone in Ethiopia*. http://hdl.handle.net/11660/6316

Wubie, A. M., de Vries, W. T., & Alemie, B. K. (2020). A Socio-Spatial Analysis of Land Use Dynamics and Process of Land Intervention in the Peri-Urban Areas of Bahir Dar City. *Land*, *9*(11), 445. https://doi.org/10.3390/LAND9110445

Xu, H. (2008). A new index for delineating built-up land features in satellite imagery. *International Journal of Remote Sensing*, *29*(14), 4269–4276. https://doi.org/10.1080/01431160802039957

Xueqin, L., Stringer, L. C., & Dallimer, M. (2022). The Impacts of Urbanisation and Climate Change on the Urban Thermal Environment in Africa. *Climate 2022, Vol. 10, Page 164*, *10*(11), 164. https://doi.org/10.3390/CLI10110164

Yesuph, A. Y., & Dagnew, A. B. (2019). Land use/cover spatiotemporal dynamics, driving forces and implications at the Beshillo catchment of the Blue Nile Basin, North Eastern Highlands of Ethiopia. *Environmental Systems Research*, *8*(1), 1–30. https://doi.org/10.1186/S40068-019-0148-Y

Youssef, A., Sewilam, H., & Khadr, Z. (2020). Impact of Urban Sprawl on Agriculture Lands in Greater Cairo. *Journal of Urban Planning and Development*, *146*(4), 05020027. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000623

Zhang, Y., Liu, S., Cheng, F., & Shen, Z. (2017). WetSpass-Based Study of the Effects of Urbanization on the Water Balance Components at Regional and Quadrat Scales in Beijing, China. *Environmental Systems Research*, *10*(1), 5. https://doi.org/10.3390/W10010005

Zhao, L., Lee, X., Smith, R. B., & Oleson, K. (2014). Strong contributions of local

background climate to urban heat islands. *Nature 2014 511:7508*, *511*(7508), 216–219. https://doi.org/10.1038/nature13462

Zingoni de Baro, M. E. (2022). Curitiba Case Study. *Cities and Nature, Part F341*, 117–162. https://doi.org/10.1007/978-3-030-90559-0_6

CHAPTER 3

3. EVALUATING INSTITUTIONAL EFFECTIVENESS IN URBAN CLIMATE GOVERNANCE: THE CASE OF BAHIR DAR CITY, NORTHWESTERN ETHIOPIA

Based on publication:

Melese, M., Anteneh, M., & Bantigegn, S. (2026). Evaluating institutional effectiveness in urban climate governance: The case of Bahir Dar City, Northwestern Ethiopia. City and Environment Interactions, 29(20), 100316. https://doi.org/10.1016/j.cacint.2026.100316

Abstract

Rapid urbanization and climate change present a serious dual challenge for cities in the Global South. Effective UCG is vital for building resilience, yet its institutional effectiveness remains under-examined. This study provides a mixed-methods assessment of UCG in Bahir Dar, Ethiopia. Quantitative data from a survey of 162 experts were analyzed using the Relative Importance Index (RII) and Analysis of Variance (ANOVA), and systematically triangulated with qualitative insights from 16 key informant interviews and document analysis. The results reveal a critically inadequate governance system (Overall Index = 0.489). The most significant finding is a systemic "policy-implementation chasm" while formal accountability mechanisms showed moderate functionality (RII=0.639), they were rendered ineffective by a near-total failure in the enforcement of climate laws (RII=0.400); the weakest link in the entire governance chain. Inferential analysis confirmed this structural disconnect, revealing a significant perceptual gap ($p<0.05$) between regional and local officials regarding awareness-raising efforts. This core failure was compounded by profound weaknesses in participation, equity, and institutional capacity. The study's primary limitation is its reliance on government expert perceptions for quantitative data, a constraint mitigated by qualitative triangulation with non-state actors. The study concludes that Bahir Dar's UCG framework is a primary barrier to achieving climate resilience. Transformative reforms focusing on legal enforcement and inclusive participation are urgently needed. This study offers a replicable framework for diagnosing UCG effectiveness in similar rapidly urbanizing contexts.

Keywords: Climate Governance, Climate Resilience, Institutional Effectiveness, Bahir Dar.

3.1. Introduction

The world is increasingly urbanizing, a trend that is particularly noticeable in developing countries, where cities are growing rapidly and facing the dual challenge of urbanization and climate change (Almulhim et al., 2022; Cohen, 2004; Li et al., 2020; Pande et al., 2023). With over half the world's population currently residing in urban areas, projected to reach 70% by 2050, the pressure on cities to adapt to climate change is rising (Dodman et al., 2022; UNECA, 2022). Africa, with its rapidly expanding urban centers, is at the front of this trend, with projections indicating a doubling of its population by 2050 due to urbanization (Berry, 2008; Brenner, 2013; Henderson, 2005; Menashe & Bocquier, 2021; UNECA, 2018). This growth presents significant governance challenges, especially in planning and executing climate change adaptation and mitigation measures.

Ethiopia, one of Africa's rapidly urbanizing nations, is witnessing urbanization rates among the highest on the continent. According to the CSA (2018), the country has an annual urbanization rate of 4.1%, while other sources, such as the World Bank (2015), estimate an even faster rate of 5.4%. Projections suggest that 42% of Ethiopia's population will live in urban areas by 2050 (Tessema, 2017). Although this rapid urban growth offers economic opportunities and improved infrastructure, it also presents challenges, including inadequate housing, overstretched public services, and environmental degradation (Abebe, 2024; Raihan, 2023).

These combined effects, together with climate change, place considerable pressure on local governments to plan for sustainable growth and equitable distribution of resources. As emphasized in NAP-ETH (FDRE, 2019), "*Ethiopia is vulnerable to the impacts of climate change and the unpredictability of climate variability*," which is shown in shifting temperature and precipitation patterns, impacting regional and global weather systems (Alizadeh, 2023; IPCC, 2022b). In northeast Africa, temperature increases of 1.2°C-4.4°C and variable precipitation patterns have already been observed (Almazroui et al., 2020). In Ethiopia, projections indicate rising temperatures and varying rainfall patterns (Birara et al., 2020; Getachew and Manjunatha, 2021; Kuma et al., 2022; Orkodjo et al., 2022). These linked challenges of urbanization and climate variability emphasize the need for adaptive and integrated UCG frameworks capable of addressing climate mitigation and adaptation essentials (Castán Broto & Westman, 2020; Solorio, 2021).

The post-Paris Agreement era of climate governance has shifted the focus from global pledges to local implementation. The success of ambitious Nationally Determined Contributions (NDCs), like those pledged by Ethiopia, now hinges directly on the implementation capacity of sub-national and local governments (UN-Habitat, 2024). As the primary sites of energy consumption, infrastructure development, and climate vulnerability, cities are the critical arenas where these national ambitions will either succeed or fail. This reality makes effective municipal governance the essential link between national policy and on-the-ground resilience.

UCG refers to the system of institutions, policies, and processes through which cities plan for and respond to climate change (Castán-Broto, 2020; Keenan et al., 2019). While national governments typically set overarching climate agendas, it is at the municipal level where these commitments must be translated into concrete action. The perceived effectiveness of UCG therefore depends heavily on the institutional capacity and effectiveness of local governments, their ability to interpret national goals and operationalize them within local realities (Averchenkova et al., 2024). This extends beyond the preparation of climate plans; it requires mobilizing adequate resources, fostering meaningful stakeholder participation, navigating political and administrative complexities, and ensuring consistent regulatory enforcement (Aminpour et al., 2022). When local institutions lack these capabilities, national climate strategies remain aspirational, leaving cities highly vulnerable to climate risks. Thus, critically assessing institutional effectiveness at the city level is essential to understanding the conditions under which urban climate actions succeed or fail.

The challenge of establishing effective UCG is a global phenomenon, though its manifestations vary by context. In the Global North, cities like Rotterdam in Europe have pioneered advanced, technology-driven adaptive governance approaches, focusing on large-scale infrastructure and sophisticated climate modeling (Hölscher et al., 2019). In North America, cities often grapple with political polarization and jurisdictional fragmentation, which can hinder cohesive climate action despite high technical capacity (Egan & Mullin, 2024). In contrast, the challenges in the Global South are often more foundational. Study in Asian megacities like Dhaka and Jakarta highlights how rapid, informal urbanization consistently outpaces the capacity of formal planning and enforcement institutions, leading to heightened vulnerability (Roy, 2021). Similarly, studies across other African cities, from Lagos to Nairobi, consistently identify a critical implementation gap, where ambitious national policies are undermined by severe deficits in municipal finance, technical expertise, and stakeholder coordination at the local level

(UNECA, 2025). It is within this specific context of the Global South, characterized by high vulnerability and constrained institutional capacity that this study is situated.

As a secondary city experiencing explosive population growth, rapid land-use transformation, and increasing pressure on its ecological resources, Bahir Dar City serves as a compelling and representative case for examining these challenges (Adigeh & Abebe, 2023; Digafe et al., 2024). Its status as a regional capital and a hub for tourism and investment concentrates the dual pressures of development and climate vulnerability, including increased flood risk and microclimate alteration (Getu & Bhat, 2024). The city's struggle to implement Ethiopia's national climate policies, such as the NAP-ETH, at the local level makes it an ideal for diagnosing the institutional barriers that prevent policy from becoming practice. The lessons learned from Bahir Dar's governance system, therefore, hold significant relevance for other African cities facing a similar problem.

Despite the critical importance of local institutions, their effectiveness remains severely under-examined, particularly in secondary cities of the Global South (Heijden, 2019). While studies have highlighted governance inadequacies in Ethiopia's capital, Addis Ababa (Addis et al., 2022), the unique challenges facing rapidly growing regional centres like Bahir Dar remain largely under explored. Existing governance indicators often fail to capture the granular, on-the-ground realities of institutional performance, overlooking critical dimensions such as policy enforcement, resource mobilization, and stakeholder equity.

This creates a critical knowledge gap that understand the national ambitions for climate action, but that lack a systematic diagnosis of the institutional effectivness at the local level to actually deliver on them. This study addresses this gap by asking *how effective is the institutional framework of UCG in Bahir Dar City*? Guided by the central hypothesis that a significant policy-implementation gap exists between national policy ambitions and local implementation capacity, this study systematically evaluates perceived governance performance across seven key dimensions. In doing so, this study moves beyond broad policy assessments to provide a detailed, evidence-based assessment of the specific institutional strengths and weaknesses that are shaping Bahir Dar's climate future.

Methodologically, this study introduces a replicable mixed-methods framework that operationalizes UCG effectiveness through a composite RII, providing a nuanced, quantitative indicative tool that is critically needed for data-scarce urban contexts. By applying this framework to Bahir Dar, a city whose rapid, unplanned growth and climate vulnerability are

representative of challenges across Sub-Saharan Africa, this study does more than just analyze a single case. It offers a transferable model for analysis and provides findings with significant reference value for other African cities striving to build climate resilience.

3.1.1. Theoretical Framework for Evaluating Institutional Effectiveness in UCG

A central premise of governance theory is that the quality of institutions directly shapes societal outcomes. In the context of urban climate change, the desired outcome is enhanced climate resilience; the ability of a city to withstand and adapt to climate shocks. The perceived effectiveness of UCG, therefore, is a measure of how well a city's institutional framework is structured to produce this outcome. To evaluate this, this study develops a robust theoretical framework to define, operationalize, and evaluate institutional effectiveness. Drawing from mainstream governance theories, this study conceptualizes institutional effectiveness through a framework that integrates three core theoretical pillars, which in turn provide the rigorous justification for the seven dimensions of analysis. This multi-dimensional framework, which serves as the conceptual model for the entire evaluation, is schematically illustrated in Figure 3.1.

First, drawing on New Institutionalism and Climate Justice theories, the study identify the foundations of legitimate governance. New Institutionalism posits that governance outcomes are determined by both formal institutions (the written laws, regulations, and property rights) and informal institutions (the unwritten norms, social conventions, and codes of conduct) that together constitute the "rules of the game" (North, 1990). For UCG, this means effective climate action requires not only robust formal rules, such as Law and Enforcement and clear Accountability structures, but also the alignment of these rules with the prevailing informal norms of political and social behavior. However, Climate Justice theory demands that both formal and informal institutions are not merely efficient but also just (Furnaro & Kay, 2022). Therefore, Equity, ensuring the fair distribution of benefits and burdens and protecting the vulnerable, is a foundational, non-negotiable component of legitimate climate governance.

Second, based on Collaborative and Polycentric Governance theories, this study assesses the dynamics of collaborative action. In the face of "wicked problems" like climate change, simple top-down or bottom-up approaches are insufficient. Effective UCG is inherently polycentric, requiring coordination across multiple, overlapping centers of authority; from national ministries and regional bodies to municipal agencies, private sector actors, and community groups (Jordan, 2018). The effectiveness of this complex web of actors hinges on the principles

of collaborative governance, which emphasizes the active involvement of all stakeholders in decision-making (Nabatchi & Emerson, 2023). This pillar, therefore, evaluates the extent and quality of stakeholder Participation and the effectiveness of Awareness-Raising.

Third, informed by Adaptive Governance theory, the study analyze the Capacity for Resilience. It is crucial here to distinguish between institutional capacity and institutional effectiveness. In this framework, capacity is understood as a critical input to the governance system, while effectiveness is the overall outcome. An institution cannot be effective without capacity, but capacity alone does not guarantee effectiveness. Adaptive Governance theory suggests that a resilient system must be able to learn, respond to new information, and manage uncertainty (Nabatchi & Emerson, 2023). This requires the development of adaptive institutions, formal and informal rules and structures that are designed for flexibility, learning, and experimentation (Chaffin et al., 2014). This pillar therefore assesses two key components of this adaptive potential; the fundamental Institutional Capacity (the inputs of resources, expertise, autonomy) needed to act, and the systemic Adaptability (the processes of learning and change) needed to navigate a dynamic world.

By integrating these theoretical perspectives, this study's seven-dimension framework provides a comprehensive tool for diagnosis. For the purposes of this study, "institutional effectiveness" is therefore the core construct, operationally defined as the perceived capacity of the UCG system to perform three core functions: 1) establishing legitimate foundations through clear, enforceable, and equitable rules; 2) fostering collaborative action through inclusive participation and shared understanding; and 3) building the capacity for resilience by mobilizing resources and adapting to change. As illustrated in Figure 1, the seven analytical dimensions (Accountability, Participation, Equity, Awareness-Raising, Institutional Capacity, Adaptability and Climate Change Law and Enforcement) are the empirical variables used to measure these three core functions.

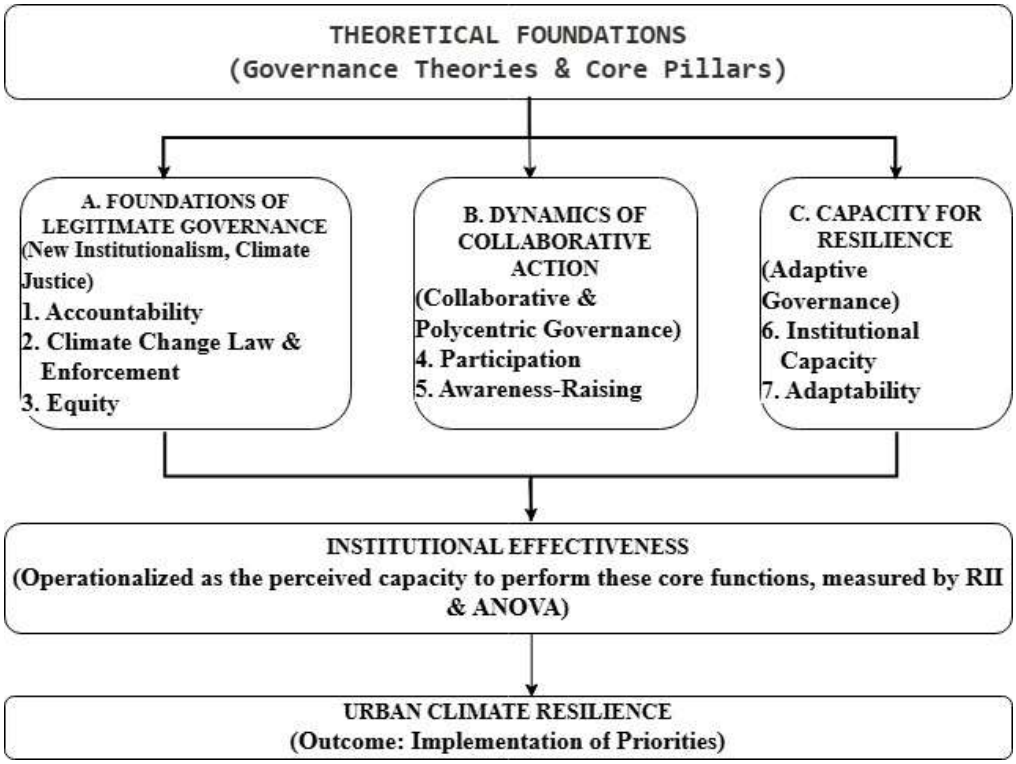


Figure 3.1 Theoretical Framework of the objective

3.2. Methods and materials

3.2.1. Study area description

3.2.1.1. Location

Bahir Dar is a major urban center in ANRS, Ethiopia, known for its rapid growth and cultural significance as a key tourism centre, including landmarks such as the Lake Tana Monasteries and the Blue Nile Falls. Geographically, Bahir Dar is located between 11°25'11" to 11°58'11" N latitude and 37°2'2" to 37°42'4" E longitude (Figure 3.2), covering ≈234.89 km² (Asmamaw & Debie, 2023). The city's topography is primarily flat, with elevations ranging from 1,708 m in the southeast to 2,007 m in the eastern and western peripheries. The predominantly level topography, with some steep slopes along Abay river gorges, allows for diverse urban development (Getu & Gangadhara Bhat, 2024; Haregeweyn et al., 2012).

3.2.1.2. History

Bahir Dar's history can be traced back to the 14th century with the founding of St. Kidane Miheret Church, and its name, meaning "a town situated very close to water body," reflects its geographical context (Appelhans, 2017). Bahir Dar began to develop urban characteristics during the Italian occupation (1936-1941) and experienced substantial growth after liberation (1941-1974) (Seyoum, 2014). The city was later designated for significant development by the

Ethiopian government due to its strategic location and abundant resources. Post-1994, Bahir Dar became the capital of ANRS (Haregeweyn et al., 2012), leading to a new wave of rural to urban migration. Between 2017 and 2022, urbanization rates increased by 7% annually (Adigeh & Abebe, 2023), transforming the city into administrative, economic, and cultural centre in Ethiopia.

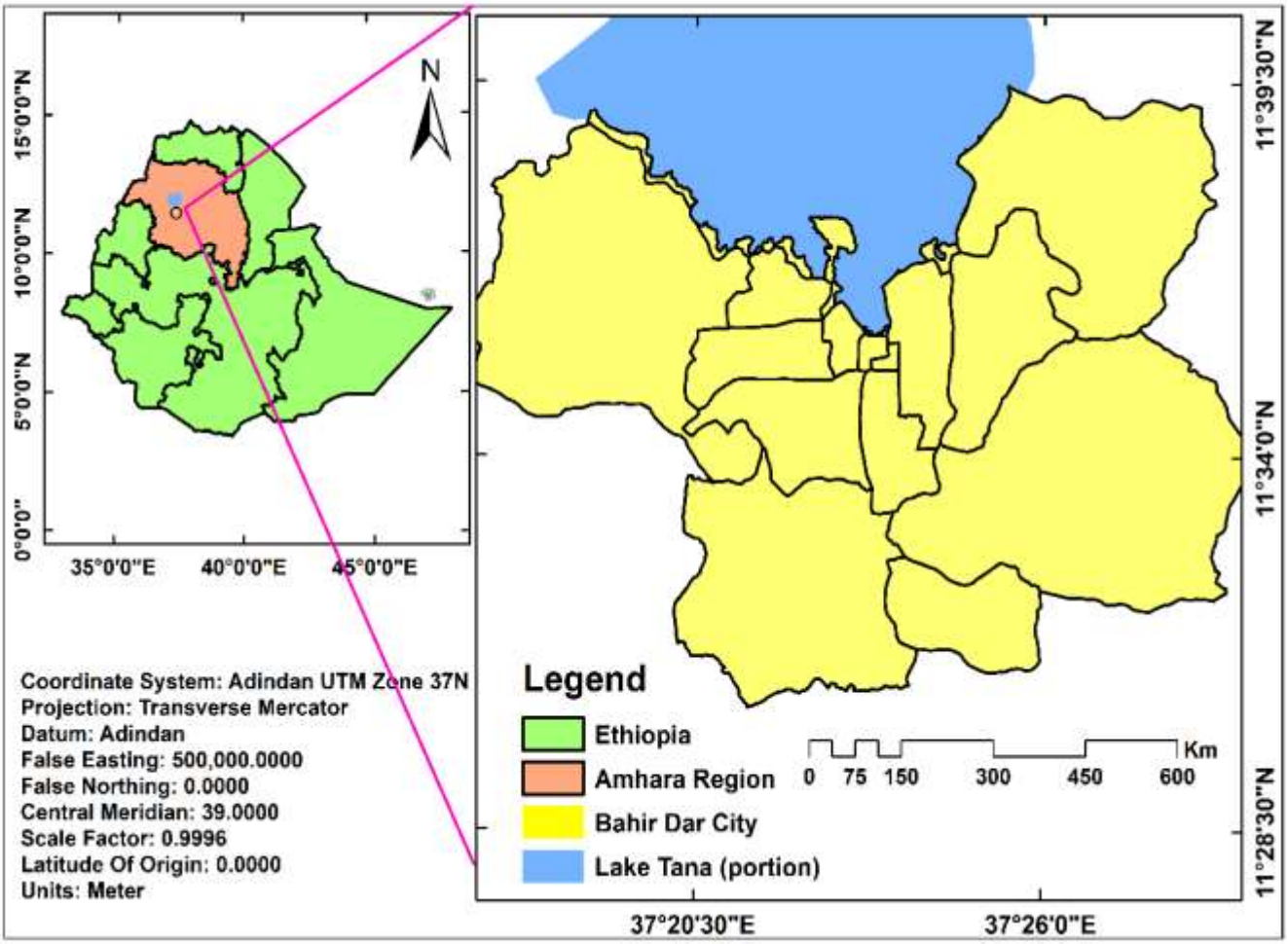


Figure 3.2 Study area map

3.2.1.3. Population and Economic activities

Bahir Dar has experienced significant population growth, increasing from 54,766 in 1984 to 180,094 in 2007 (CSA, 1984, 2007). While more recent census data is unavailable, estimates from 2017 and 2020 put the population at around 362,297 and nearly 500,000, respectively (Bahir Dar City Structural Plan Preparation Project Office, 2020; CSA, 2013a). This rapid population growth underlines the urgent need to address the challenges associated with rapid urbanization. Bahir Dar's economy is diverse, with key sectors including horticulture, agro-industrial processing, agriculture, manufacturing, and diverse service industries (UNESCO, 2015).

3.2.1.4. Temperature and Rainfall

Bahir Dar experiences a moderate climate characterized by distinct wet and dry seasons. Temperatures range from cooler averages of 18-20°C in January and February to warmer periods of 22°C in March and April. Over the long term (1984-2022), the city recorded average minimum and maximum temperatures of 11.4°C and 27.4°C, respectively, with a notable warming trend since 2008 (NASA's Climate data). Bahir Dar's rainy season spans March to September, with peak rainfall between June and August (238-437 mm). The drier months, January and February, see minimal rainfall (3-8 mm). Bahir Dar's variable climate underscores the need for sustainable climate adaptation strategies.

3.2.2. Research Approach and Design

This study adopted a mixed-methods approach using a convergent parallel design to assess the institutional effectiveness of UCG. Quantitative data from survey questionnaires were collected concurrently with qualitative data from key informant interviews (KIIs), field observations, and document reviews. Following the convergent design, both data types were analyzed separately and then systematically integrated during the interpretation stage to provide a comprehensive and triangulated understanding of the research problem (Tashakkori & Teddlie, 2003). The selection of the case study itself was a critical component of the research design, as detailed below (Figure 3.3).

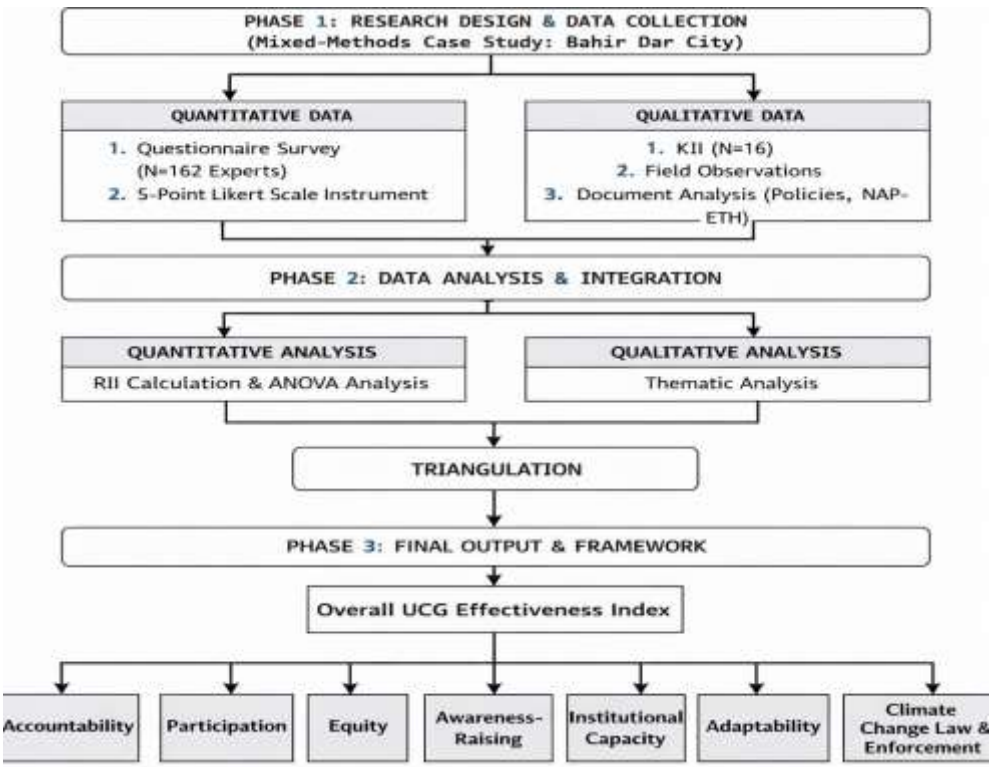


Figure 3.3 Flow Chart of the study

3.2.2.1. Case Selection and Research Design Rationale

The single-case study was chosen as it is exceptionally well-suited for an in-depth, holistic investigation of a contemporary phenomenon within its real-world context. Bahir Dar City was purposively selected as a critical and archetypal case for examining the institutional effectiveness of UCG in a rapidly urbanizing Global South context. A "critical case" is one that can intensely test a general theory or proposition. The central proposition, or hypothesis, guiding this study is that a significant "policy-implementation gap" exists, where the perceived effectiveness of UCG is significantly lower at the local implementation levels (city and sub-city) compared to the regional policy-making level. Bahir Dar provides an ideal context to test this proposition; as a regional city attempting to implement Ethiopia's national climate policies (like the NAP-ETH), it is a prime location for diagnosing the specific institutional effectivness that prevent national ambitions from becoming local practice.

The fit of Bahir Dar for this investigation is exceptionally strong for several reasons. First, as a regional city experiencing explosive growth after becoming a regional capital, it is emblematic of the urbanization patterns across Sub-Saharan Africa, which are concentrated in small and intermediate cities rather than megacities. This makes its challenges more representative than those of the capital, Addis Ababa. Second, the city exhibits the classic "policy-implementation gap" where ambitious national climate goals confront the on-the-ground realities of resource constraints, rapid informal settlement, and competing developmental priorities. Third, its well-defined administrative structure and diverse array of stakeholders (government, CSOs, private sector) provide the necessary empirical richness to evaluate all seven dimensions of the UCG framework.

The boundary conditions of this study are clearly defined. Spatially by the administrative limits of Bahir Dar City. Conceptually, it is bounded by the study's seven-dimension UCG framework, focusing specifically on institutional processes and stakeholder perceptions rather than a quantitative measurement of biophysical climate impacts. The actors are bounded by the purposively selected sample of experts and key informants, whose perspectives are triangulated to construct a comprehensive view of the governance system.

The theoretical significance of selecting Bahir Dar lies in its potential for analytical generalization. While the specific findings are context-bound, the patterns of institutional failure and success, the nature of the policy-implementation gap, and the challenges of multi-level governance diagnosed in this study are highly transferable. They provide a powerful and

evidence-based reference for understanding and improving UCG in countless other secondary cities across the Global South facing a similar difficulties of rapid urbanization and climate vulnerability.

3.2.2.2. Data Sources and Collection Tools

This study employed a mixed-methods approach to evaluate UCG effectiveness, integrating primary and secondary data for comprehensive analysis and triangulation.

A. Primary Data

I. Questionnaire Survey

A structured, Likert-scale questionnaire was administered to 162 purposively selected experts. The sample was drawn from key government bodies with direct mandates for UCG, specifically the Environmental Protection and Green Development Offices at the regional, city, and sub-city levels, and the Bahir Dar City Urban Planning Office. This self-administered format was chosen to efficiently capture perceptions with consistency and minimal bias. To minimize self-grading bias, all expert respondents were guaranteed total anonymity, and surveys were collected in a way that prevented their supervisors from seeing individual answers

II. Key-informant Interviews (KII)

Sixteen semi-structured interviews were conducted with a diverse range of stakeholders, including government officials, private sector and civil society organization (CSO) representatives, and community members.

III. Field Observations

Direct observation of on-the-ground conditions, such as drainage systems, green spaces, and land-use dynamics, provided tangible evidence of governance outcomes.

B. Secondary Data

IV. Document Analysis

A systematic review of official documents including urban planning policies, budget reports, and NAP-ETH was conducted to identify the intended governance frameworks and gaps between policy and practice.

3.2.2.3. Instrument Development and Validation

To ensure the validity and reliability of the quantitative data, the questionnaire was developed through a multi-stage process. First, the seven main indices and 44 sub-indicators were derived from a comprehensive review of established governance literature and indices (Addis et al.,

2022; Assele, 2019; Beyene et al., 2023; UN-Habitat, 2004) and were carefully adapted to the specific urban and climate context of Bahir Dar.

Second, the instrument underwent a two-step validation process. Content validity was established through a review by a panel of five academic experts and three local governance practitioners, who assessed the clarity, relevance, and comprehensiveness of each item. Based on their feedback, several items were rephrased for clarity. Following these revisions, a pilot test was conducted with 10 experts (not included in the final sample) to identify any remaining ambiguities in wording or format and to refine the overall flow of the questionnaire before full administration.

Finally, the internal consistency and reliability of the instrument were statistically confirmed using Cronbach's Alpha for each of the seven indices. As detailed in the Results section, all indices demonstrated acceptable to high reliability ($\alpha > 0.70$), confirming that the sub-indicators for each dimension consistently measure the same underlying construct. This multi-stage process ensures that the survey instrument is a valid and reliable tool for assessing perceived UCG effectiveness in Bahir Dar.

3.2.2.4. Sampling Design and Procedure

Bahir Dar City was purposively selected as the case study area due to its rapid urbanization and vulnerability to climate variability (Adigeh & Abebe, 2023; Digafe et al., 2024; Getu & Gangadhara Bhat, 2024), making it an important case for analyzing UCG effectiveness. A mixed-methods sampling approach was used, with distinct strategies for the quantitative and qualitative components of the study.

For the quantitative survey, a census approach was used to include all available experts (N=162) from the relevant Environmental Protection, Green Development, and urban planning offices at the regional (n=17), city (n=37), and sub-city (n=108) levels. This census of the defined expert population was chosen over sampling to capture the complete spectrum of professional perspectives within the formal governance structure. These experts were selected based on their relevant experience and direct involvement in climate action implementation, ensuring the quantitative data came from practitioners with technical and managerial knowledge of the formal governance structure.

To complement these quantitative findings with deeper, multi-stakeholder insights, a purposive and maximum variation sampling strategy was used to identify 16 key informants for semi-structured interviews. This qualitative sample was intentionally stratified to capture the full

spectrum of power, knowledge, and experience. The composition of this sample included six government officials (two from each administrative level), four community members chosen for their long-term experience with climate impacts, three private sector representatives from climate-relevant sectors, and three leaders from actively engaged Civil Society Organizations (CSOs). This mixed-methods strategy provides a deep internal investigation of the government's perspective (quantitative) and the rich, external context from non-state actors (qualitative) for robust triangulation and mitigation of potential bias.

3.2.3. Methods of Data Analysis

3.2.3.1. Quantitative Data Analysis

The quantitative data was analyzed using the RII to determine the relative importance of different sub-indicators within each dimension of UCG and one-way analysis of variance (ANOVA) to test for significant differences in perceptions across administrative levels. The study's framework consists of seven main dimensions, which are rigorously derived from the synthesis of governance theories as outlined in the introduction. The 44 specific sub-indicators were developed based on a comprehensive review of existing governance literature and indices of UN-Habitat urban governance index, Assels's Environmental Governance index and Addis Climate Governance index (Addis et al., 2022; Assele, 2019; Beyene et al., 2023; UN-Habitat, 2004). This study carefully adapted to operationalize these theoretical dimensions within the specific context of Bahir Dar.

To quantify the level of expert agreement with statements of governance performance, the Likert-type questionnaire data were analyzed using the RII. While RII is often used to rank importance, in this context, it serves as a robust tool to transform ordinal perception data into a continuous 0-1 scale, representing the collective level of agreement among experts (Azman et al., 2019; Tholibon et al., 2021). This focus on expert perception is a deliberate methodological choice. In the complex, multi-actor domain of governance, where objective performance data is often unavailable or contested, the collective, triangulated perception of experienced practitioners provides the most reliable and nuanced representation for assessing the functionality of institutional processes. A score of 1.0 would indicate universal "Strongly Agree" responses, while a score of 0.2 would indicate universal "Strongly Disagree" responses. The RII was calculated by Equation (13).

$$RII = \sum W/(A * N) \qquad (13)$$

Where

∑W = (W1 + W2 + W3 + ... + Wn);

W = Weighting assigned on Likert's scale by each respondent, ranging from 1 to 5 (where 1 = strongly disagree and 5 = strongly agree);

A = Highest weight (here it is 5);

N = Total number in the sample.

Following standardization, the values for the sub-indicators were averaged to generate an overall score for each of the seven dimensions. This was achieved using Equation (14).

$$V1 = \frac{\sum I}{N} \quad (14)$$

V1 = The value for one of the 7 indicators

∑(I) = The sum of the standardized values for indicators under that specific index

N = The number of indicators in that index

Then, a weighted average was calculated across all the seven dimensions to create a single composite index that represents the perceived effectiveness of UCG in Bahir Dar city. The composite UCG index was calculated using Equation (15).

$$X = \frac{(A_1 * W_1) + (A_2 * W_2) + (A_3 * W_3) + \cdots + (A_7 * W_7)}{\sum_{i=1}^{n=7} (Wi)} \quad (15)$$

Where:

X = Composite index

A = Indicator value

W = Weight of the specific index (number of indicators comprising the index)

The resulting index score was then compared to a methodologically derived threshold of 0.50. This threshold is not an arbitrary performance benchmark but represents the mathematical midpoint of the 5-point Likert scale's response range, corresponding to a hypothetical average response of 2.5. This is the precise point dividing disagreement (scores 1-2) from agreement (scores 3-5). Therefore, index scores below 0.50 are interpreted as indicating a general consensus of disagreement with an effectiveness statement, while scores above 0.50 indicate a general consensus of agreement. However, it is crucial to note that while 0.50 is the mathematical midpoint, in the context of governance performance, it represents an absolute

minimum threshold of perceived functionality. Therefore, scores falling below this critical line are interpreted in this study not merely as weak, but as indicative of a significant governance failure. This approach provides a clear, justifiable basis for interpreting the overall valence of expert perceptions (Addis, 2023; Assele, 2019). All quantitative analyses were performed using SPSS Statistics (Version 28.0).

In addition to the descriptive RII analysis, inferential statistics were employed to test for significant differences in perceptions across administrative levels. ANOVA was conducted for each of the seven UCG indices, with the expert's level of government (regional, city, or sub-city) serving as the independent variable. The assumption of homogeneity of variances was assessed using Levene's test and was met for all seven dimensions ($p > .05$ for all). Where the overall ANOVA was found to be statistically significant ($p < .05$), a Tukey HSD post-hoc test was performed to identify which specific groups differed in their perceptions.

3.2.3.2. Qualitative Data Analysis and Triangulation

Qualitative data from the semi-structured KIIs and field notes were analyzed using the thematic analysis framework of Braun & Clarke, (2006). To ensure rigor and transparency, a formal codebook was developed, its reliability confirmed through an inter-coder agreement process, and the resulting thematic map underwent peer debriefing. The research team also maintained a stance of reflexivity regarding the data collection and analysis. While the use of five trained enumerators (all of whom held postgraduate degrees in Geography and Environmental Studies) helped minimize direct researcher bias during the interviews, the analysis required critical self-reflection on the authors' own familiarity with the local context. To mitigate potential interpretive bias, the research team engaged in regular debriefing sessions with the enumerators to capture non-verbal cues and strictly grounded all emerging themes in the verbatim transcripts rather than prior assumptions.

The central analytical strategy of this study was triangulation, which was systematically employed during the interpretation stage to verify and enrich the findings. Each emerging qualitative theme was not considered robust until it was cross-validated against the study's other data sources. This involved a multi-step verification process. First, the qualitative themes explaining governance failures were directly compared with the quantitative statistical results (the RII and ANOVA scores), allowing the qualitative data to provide the causal explanation for the numerical findings. Second, themes from interviews such as those regarding poor infrastructure or a lack of public engagement were verified against the evidence gathered

during direct field observations. Finally, perceptions of policy failures were checked against the stated goals and mechanisms within the official policy documents, such as the NAP-ETH and municipal planning frameworks, to precisely identify and confirm specific policy-implementation gaps. By ensuring that each major conclusion was supported by converging evidence from interviews, statistics, observations, and documents, this approach provided a comprehensive and rigorously validated understanding on the effectivness UCG in Bahir Dar.

3.3. Results and Discussion

The following sections present an integrated analysis of the seven key dimensions of UCG in Bahir Dar City. This study used a mixed-methods approach, combining quantitative data collected through a survey questionnaire with experts using a 5-point Likert scale and qualitative insights from semi-structured KIIs. The quantitative data were analyzed using the RII to compute an effectiveness index and ANOVA to examine perceptual gaps across administrative levels. These findings are systematically triangulated with thematic analysis of interviews, field observations, and secondary data from document analysis to provide further context, explanation, and validation.

3.3.1. Reliability Analysis of UCG Indicators

As shown in Table 3.1, the internal consistency of the sub-indicators within each UCG index was assessed using Cronbach's Alpha. All indicators yielded alpha values above the commonly accepted threshold of 0.70, indicating acceptable to high reliability. The Participation and Adaptability indicators exhibited particularly strong reliability (α = 0.83 and 0.81, respectively), suggesting that the grouped sub-indicators consistently captured their intended constructs. This reliability analysis strengthens the credibility of the quantitative results by confirming that the seven governance dimensions were measured using statistically coherent and internally consistent indicators.

Table 3.1 Cronbach Alpha (α) Value of Indicators

UCG Index	Number of Sub-Indicators	Cronbach's Alpha (α)	Interpretation (Babbie, 2013)
Accountability	4	0.78	Acceptable reliability
Participation	7	0.83	High reliability
Equity	8	0.80	High reliability
Awareness-Raising	5	0.75	Acceptable reliability
Institutional Capacity	4	0.79	Acceptable reliability
Adaptability	9	0.81	High reliability
Climate Change Law and Enforcement	7	0.77	Acceptable reliability

3.3.2. Accountability in Urban Climate Governance

Accountability, a cornerstone of effective governance, was evaluated through four sub-indicators focusing on government responsibility for decisions intensifying climate change, enforcement of climate protection laws, responsiveness to vulnerable communities, and transparency in managing climate-related budgets (Hughes et al., 2020; UN-Habitat, 2023).The overall accountability index of 0.639 (Table 3.2) suggests a moderate but inconsistent perceived performance, a finding elaborated by the sub-indicator analysis. Accountability for decisions that worsen climate change (Sub-Indicator 1.1) received the highest score (RII = 0.720), suggesting that a relatively effective formal system exists for holding decision-makers responsible.

Table 3.2 Accountability Sub-Indicators and RII Values

	Sub-indicator	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII
		%					
1.1	Government bodies accountability for decisions that intensify climate change	10.3	3.9	15.8	55.2	14.8	**0.720**
1.2	Authorities accountability for violations of laws related to climate change protection	30.5	7.9	15.3	40.9	5.4	**0.566**
1.3	Government institutions responsiveness to the needs of communities vulnerable to climate change	19.7	8.4	22.7	42.9	6.4	**0.616**
1.4	Budget performance audit for climate change activities within government institutions	17.8	3.9	19.2	50.7	8.4	**0.656**
Overall Accountability Index							**0.639**

However, qualitative data revealed that despite existing review processes, accountability is often undermined. A regional official noted, "*the enforcement of corrective actions is often slow due to resource constraints and political pressures*," while another admitted, "*When decisions are already made, it is sometimes difficult to reverse them due to bureaucratic delays*." This suggests that political and bureaucratic hurdles hinder effective accountability, a challenge consistent with Guerzovich and Wadeson's (2024) work on complex governance systems. This weakness is worsened by the limited use of climate impact assessments in urban decision-making.

In contrast, accountability for violations of climate protection laws (Sub-Indicator 1.2) scored the lowest (RII = 0.566), indicating a significant enforcement deficit. This was intensely

illustrated by community experiences. A community member shared, "*Even though we reported illegal sand mining to local authorities, no action was taken*," and another noted that regarding a polluting textile factory, "*it took over a year for the government to take action... It seems like the authorities were not held accountable*." Such accounts point to inconsistent law application, a recurring issue in developing countries that undermines governance credibility (Aggarwal et al., 2022). Further analysis of the Bahir Dar City Environment Protection Regulations (2017) confirms this gap, revealing a lack of clear implementation and enforcement mechanisms.

The responsiveness of government institutions to vulnerable communities (Sub-Indicator 1.3) registered a moderate RII of 0.616. This score indicates that government bodies are making some effort to address community needs and are not entirely unresponsive. KIIs suggested that while some efforts exist, they are often superficial. A community leader acknowledged that the government provides "*occasional training on sustainable farming practices*," but added, "*there is little follow-up, and we rarely see any real action when problems arise*." This reflects a need for sustained engagement rather than occasional events, particularly for marginalized groups, which is a point emphasized by IPCC (2022a). Field observations in informal settlements confirmed that support mechanisms often fail to reach those most in need.

Finally, the presence of perceived budget performance audits (Sub-Indicator 1.4) scored RII of 0.656, suggesting that formal mechanisms for financial oversight are officially in place and are expected to be carried out. However, this perception of a functioning formal system is undermined by qualitative data, which exposed deep-seated issues with a lack of practical transparency. A CSO leader stated, "*Our efforts are often hindered by a lack of access to government data and resistance from some officials*." This was supported by a government official who admitted, "*a recurring challenge is the inconsistency in reporting by implementing agencies, which complicates our auditing process*." These systemic barriers to financial oversight erode public trust, as noted by Freitas et al. (2024). A review of Bahir Dar's annual reports confirmed this, showing that while budgets are allocated, detailed information on climate finance implementation is inadequate and lacks transparency.

Interpreted through a New Institutionalism lens, these findings on accountability reveal a classic and critical conflict between the city's formal and informal institutions. The empirical data strongly indicates that formal accountability mechanisms exist on paper but are neutralized by powerful informal institutions. The qualitative narratives detailing "political pressures,"

"bureaucratic delays," and "resistance from some officials" serve as direct evidence of this conflict, showing that the real, functioning governance system prioritizes unwritten norms over official mandates. This divergence explains why the lowest-scoring sub-indicator was accountability for the actual enforcement of laws (RII=0.566). Analytically, this demonstrates that achieving effective accountability requires not merely establishing new rules but designing specific policy interventions (such as independent enforcement units) that can structurally counter the inertia of informal political norms.

3.3.3. Participation in Urban Climate Governance

Participation is a critical component of effective climate action, ensuring governance is inclusive and responsive (Arnstein, 2019). This study assessed participation through seven sub-indicators. The findings, however, reveal significant shortcomings, with an Overall Participation Index of 0.485 (Table 3.3), indicating that multi-stakeholder engagement in Bahir Dar's climate governance is weak and falls below the effectiveness threshold.

Table 3.3 Participation Sub-Indicators and RII Values.

	Sub-indicator	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**RII**
				%			
2.1	Private sector active participation in planning climate change governance measures	6.9	39.4	40.9	12.3	0.5	**0.520**
2.2	Civic associations involvement in planning climate change governance measures	17.2	38.4	29.6	14.8	0.0	**0.484**
2.3	Local communities participation in climate change response actions	17.2	44.8	29.1	8.9	0.0	**0.459**
2.4	Regular organization of public forums about climate change issues	25.7	30.5	30.5	13.3	0.0	**0.463**
2.5	CBOs key role in climate change governance	16.8	36.9	27.1	18.7	0.5	**0.499**
2.6	Effective involvement of various government offices in climate change governance	23.6	35.0	27.1	14.3	0.0	**0.464**
2.7	Collaboration between NGOs, local communities, and the private sector in climate change governance	22.2	27.1	27.1	22.2	1.5	**0.507**
Overall Participation Index							**0.485**

Private sector participation (Sub-indicator 2.1) scored the highest among the participation indicators with an RII of 0.520, yet this suggests engagement is only moderate and not central to the governance process. A private sector representative confirmed this, stating, "*Our*

participation is usually limited to implementing pre-designed projects. We are rarely consulted during the planning stage." This aligns with findings from other developing cities where private sector involvement is often reactive (Klein et al., 2018; Zhang et al., 2020), and highlights a failure to implement the 'principle of partnership' called for in the NAP-ETH (FDRE, 2019).

Civic associations' involvement in planning (Sub-indicator 2.2) yielded a low RII of 0.484, which confirms that their role is perceived as weak and ineffective. Qualitative data provides a clear diagnosis for this poor perceived performance, revealing a sharp disconnect between the government's perception of consultation and the CSOs' experience of it. While a government official noted, "*CSOs often provide valuable feedback during these consultations*," CSOs feel their input has limited impact, suggesting a tokenistic form of engagement. This reflects challenges identified by (UN-Habitat, 2022) where civic groups lack the capacity for full participation, pointing to a need for genuine empowerment rather than just formal consultation, a goal outlined in national policy (FDRE, 2019).

Similarly, local community participation in climate response actions (Sub-indicator 2.3) was rated low at RII = 0.459. Although communities are involved in implementation, their role in decision-making is minimal. One member explained their role was "*mainly to provide input based on our practices and participate in implementing small-scale water-harvesting projects*." This indicates a gap in achieving the 'stakeholder empowerment' proposed by NAP-ETH (FDRE, 2019) and stresses the need for resources and training to facilitate meaningful engagement, as noted by Blackburn et al. (2019).

The arrangement of public forums (Sub-indicator 2.4) also scored poorly (RII = 0.463), with interviews revealing that they are infrequent and exclusionary. A CSO leader observed, "*Public forums often lack inclusivity... Additionally, there's a gap in follow-up actions after discussions*." This prevents the 'permanent dialogue' between stakeholders called for in the NAP-ETH (FDRE, 2019) and echoes the need for accessible and effective platforms for public deliberation (Hügel & Davies, 2020).

The role of CBOs in governance (Sub-indicator 2.5) registered an RII of 0.499, indicating limited engagement. CSOs focus on grassroots activities like "*awareness campaigns*" and "*training sessions*," but a CSO leader noted that limited resources constrain their ability to engage with governing bodies. This finding is consistent with Ziervogel et al. (2022) and shows

a failure to leverage civil society capacity, despite national policies advocating for their inclusion (FDRE, 2019).

Intra-governmental involvement (Sub-indicator 2.6) was also weak, with an RII of 0.464. While one official mentioned collaboration on "*climate-resilient infrastructure projects*," the low score suggests that cross-sectoral coordination remains a significant challenge, a common issue in climate governance (Wagner et al., 2021). This points to a critical need for better implementation of the mainstreaming guidelines within the NAP-ETH (FDRE, 2019).

Finally, collaboration between NGOs, local communities, and the private sector (Sub-indicator 2.7) scored an RII of 0.507. Despite being relatively higher than other indicators, this still points to limited collaboration. Stakeholders noted the lack of a consistent platform for interaction, leading to ad-hoc engagement. This highlights a critical gap, as successful climate governance requires strong multi-stakeholder collaboration (Prabin, 2024), and the development of 'multi-stakeholder platforms' as stressed in the NAP-ETH (FDRE, 2019).

Theoretically, the low RII scores for Participation (RII=0.485) provide compelling empirical evidence of the challenges to achieving genuine Collaborative Governance. The qualitative data consistently confirms that the system operates as a hierarchical structure, a failure to build a truly polycentric system, where non-state actors are treated as passive recipients rather than essential co-producers. This participation is largely symbolic, a form of "tokenism" where stakeholders are consulted but not empowered, reflecting significant power imbalances that render formal civic involvement ineffectual. Analytically, this tokenism is a structural symptom; it prevents the integration of local knowledge and erodes the public trust necessary for collective action. Therefore, achieving effective UCG requires a policy intervention focused on structurally mandating co-production models to shift power dynamics and interrupt the "Exclusion-to-Mistrust Spiral" that currently paralyzes engagement.

3.3.4. Equity in Urban Climate Governance

Equity is critical for ensuring climate actions benefit all, especially vulnerable groups (Smith & Wodajo, 2022). However, the Overall Equity Index of 0.483 (Table 3.4) indicates a significant equity deficit in Bahir Dar's climate governance. This low score reflects systemic challenges in translating policy into equitable outcomes, with severe weaknesses observed in the practical inclusion of marginalized groups and the fair distribution of resources and benefits.

The existence of policies to protect the poor (Sub-indicator 3.1) scored a moderate RII of 0.602. However, interviews exposed a disconnect between policy and practice. A regional official admitted, "*While we do have a climate adaptation framework that mandates consideration for marginalized communities, its effectiveness in implementation is not as comprehensive as we would want it to be*." This aligns with the arguments of Stock et al. (2021) that policies often fail to translate into meaningful outcomes, a gap also evident in the Bahir Dar City's Strategic Plan for Environmental Protection (2018), which lacks specific implementation mechanisms.

Women's involvement in governance (Sub-indicator 3.2) was rated low at RII = 0.471. While women may be invited to initiatives, their participation is often superficial. A community member noted, "*While women are invited to meetings, often a few speak because we feel that our ideas won't be taken seriously*." This reflects a form of symbolic participation where underlying power imbalances that prevent genuine influence are not addressed, a challenge highlighted by Sultana (2022).

Table 3.4 Equity Sub-Indicators and RII Values

	Sub-indicator	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**RII**
				%			
3.1	Policies in place ensuring the poor are considered in climate change response efforts	24.2	3.9	24.1	42.4	5.4	**0.602**
3.2	Womens active involvement in climate change governance activities	44.3	6.9	21.7	23.2	3.9	**0.471**
3.3	Communities equitable access to climate-related resources	59.1	8.9	14.3	14.3	3.4	**0.388**
3.4	Active inclusion of marginalized groups in climate change decision-making processes	59.1	6.9	16.7	15.8	1.5	**0.387**
3.5	Adaptation and mitigation measures address the unique vulnerabilities of groups	44.3	17.2	22.2	13.3	3.0	**0.427**
3.6	Equitable distribution of climate action benefits	40.9	18.2	22.2	17.2	1.5	**0.440**
3.7	Transparent and accountable allocation of resources for climate action	30.1	13.3	27.6	25.6	3.4	**0.518**
3.8	Climate change adaptation measures consider the impact on vulnerable groups	15.8	11.3	21.2	44.8	6.9	**0.632**
Overall Equity Index							**0.483**

Equitable access to climate-related resources (Sub-indicator 3.3) and the inclusion of marginalized groups in decision-making (Sub-indicator 3.4) received the lowest scores, at RII = 0.388 and RII = 0.387, respectively. These results clearly demonstrate a critical failure in governance. A private sector representative confirmed the resource gap, stating, "*The government has some programs, but they often fail to target the people who need them the most.*" Regarding decision-making, a community member observed that when marginalized

groups are included, "*it feels more like a formality, they did not get the chance to voice their opinions*." This exclusion of vulnerable communities is a well-documented barrier to equitable adaptation (Roberts & Pelling, 2018; Zhu et al., 2024).

The design of specific adaptation measures for vulnerable groups (Sub-indicator 3.5) and the equitable distribution of benefits (Sub-indicator 3.6) also scored poorly, with RII values of 0.427 and 0.440. A community member stated, "*The measures taken so far don't directly address our challenges, there aren't specific programs targeting women*," illustrating the need for tailored interventions. Likewise, a private sector representative noted that benefits are skewed "*support programs for farmers often benefit market-oriented operations rather than subsistence-level producers*," revealing structural inequalities that drive climate injustice (Echeverri et al., 2024).

Transparency in resource allocation (Sub-indicator 3.7) scored an RII of 0.518, suggesting some mechanisms exist but lack effectiveness. This is consistent with concerns about accountability in resource distribution (Petkovic & Rahman, 2021). A government official mentioned a "*quarterly reporting system*" supplemented by "*field audits*," but field observations revealed a lack of clarity in how resources were allocated, especially in informal areas.

In contrast, considering the impact of adaptation on vulnerable livelihoods (Sub-indicator 3.8) received the highest score in this dimension (RII = 0.632). This indicates a relative strength, with efforts being made to protect community livelihoods. A CSO leader shared that their organization implemented "*training programs on sustainable agriculture*" to support local resilience. This aligns with the principle that effective adaptation must secure, not undermine, community livelihoods (Darjee et al., 2023).

Considered through the lens of Climate Justice theory, the extremely low RII scores in this dimension (RII=0.483) provide empirical evidence of a profound, systemic failure in equity. The findings point to a clear deficit in procedural justice (exclusion from decision-making, RII=0.387) and distributive justice (inequitable resource access, RII=0.388). The qualitative data confirms this, showing that inclusion is a mere "formality" and resource programs fail to target the most vulnerable. Crucially, the disconnect between existing "on-paper" policies and their failure to translate into practical outcomes demonstrates a fundamental lack of recognition justice, where the specific needs and vulnerabilities of marginalized groups are not structurally addressed. Analytically, this failure to embed justice into the fabric of governance undermines

the system's fundamental legitimacy and is the root structural cause of the "Exclusion-to-Mistrust Spiral." Therefore, effective UCG requires policy interventions that move beyond general mandates to implement specific, tailored interventions to guarantee procedural and distributive fairness.

3.3.5. Awareness-Raising in Climate Change Governance

Effective awareness-raising is crucial for enabling stakeholder engagement in climate action. However, this study reveals significant weaknesses in Bahir Dar's approach, with an Overall Awareness-Raising Index of 0.488 (Table 3.5), indicating that current efforts are largely ineffective.

Table 3.5 Awareness-Raising Sub-Indicators and RII Values

	Sub-indicator	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII
		%					
4.1	Awareness-raising campaigns targeting key actors involved in climate change measures	8.4	14.3	30.0	39.9	7.4	**0.647**
4.2	Frequent and effective awareness campaigns targeting the general community about climate change	37.9	17.3	15.8	24.6	4.4	**0.481**
4.3	Public awareness about specific actions taken to address climate change	48.3	29.1	16.7	5.4	0.5	**0.362**
4.4	Sufficient training opportunities for experts involved in climate change governance	42.4	22.7	20.2	14.3	0.5	**0.416**
4.5	Experts training effectiveness in building capacity	28.6	15.8	19.2	32.5	3.9	**0.535**
Overall Awareness-Raising Index							**0.488**

Campaigns targeting key actors (Sub-indicator 4.1) scored the highest in this dimension with an RII of 0.647. Despite this relatively positive score, qualitative evidence suggests implementation challenges. A regional official admitted, "*we have launched large scale media campaigns but the implementation has not been as effective as we had planned*." This points to a gap between planning and execution, a common issue in African cities where resource limitations hinder campaign reach (Ofoegbu et al., 2019), and fails to fully achieve the "ownership" envisioned in the NAP-ETH (FDRE, 2019).

In contrast, campaigns for the general community (Sub-indicator 4.2) were rated as ineffective, with an RII of 0.481. A community member's comment, "*I've only seen a few posters and leaflets, I feel they didn't go deep enough*," suggests that current approaches are superficial and fail to connect with local experiences. This aligns with findings that awareness programs must be relevant to daily life to be effective (Khatibi et al., 2021). Field observations confirmed that these campaigns were largely absent in the most vulnerable communities.

The most significant failure was in public awareness of specific, actionable steps (Sub-indicator 4.3), which received the lowest score in this study (RII = 0.362). This indicates a critical gap between general awareness and practical knowledge. A community member stated, "*I know some basic things like planting trees, but I still need guidance on modern farming techniques that can withstand droughts*." This highlights the need for programs that provide accessible and actionable information, moving beyond generalities, a point emphasized in recent climate communication research (IPCC, 2022a).

Training for experts also showed major deficiencies. The availability of training opportunities (Sub-indicator 4.4) scored a low RII of 0.416, with experts noting that trainings are often ad hoc and impractical. A government official observed that "*training opportunities for experts exist, they lack practicality and are not provided at the local level, where they are needed the most*," pointing to a need for sustained and accessible capacity-building as also stated by Gupta et al. (2022).

Furthermore, the perceived effectiveness of existing training (Sub-indicator 4.5) was rated as only moderately effective with an RII of 0.535. A government official explained this limited impact, stating, "*While we've conducted multiple training sessions for experts, their impact is limited because of a lack of follow-up programs and also because the programs lack practical sessions and real-life applications*." This suggests that a shift is needed from one-off events to sustained technical support to achieve lasting impact, as noted by Casado-Asensio et al. (2022).

Furthermore, the perceived effectiveness of existing training (Sub-indicator 4.5) was rated as only moderately effective with an RII of 0.535. A government official explained this limited impact, stating, "While we've conducted multiple training sessions for experts, their impact is limited because of a lack of follow-up programs and also because the programs lack practical sessions and real-life applications." This suggests that a shift is needed from one-off events to sustained technical support to achieve lasting impact, as noted by Casado-Asensio et al. (2022).

From a Collaborative Governance perspective, these findings are highly significant, as they demonstrate a systemic failure to build the "shared understanding" that is a critical theoretical precondition for effective multi-stakeholder action. The data reveals a two-tiered empirical failure. First, at the community level, awareness efforts are superficial (lowest RII=0.362 for actionable knowledge), hindering genuine public participation. Second, and more critically, the governance system itself lacks a shared understanding. This is statistically evidenced by the ANOVA-identified perceptual gap (p=.036) between regional policymakers and local

implementers regarding campaign effectiveness. Analytically, this disconnect prevents the "permanent dialogue" and mutual learning required by collaborative governance, revealing a major structural flaw. Since governance success weakens where understanding is not shared, policy must focus on creating structural dialogue platforms that institutionalize this learning and collaboration to interrupt the "policy-implementation chasm" that plagues the UCG system.

3.3.6. Institutional Capacity in Climate Change Governance

Institutional capacity is fundamental for the effective implementation of climate strategies. The Overall Institutional Capacity Index of 0.483 for Bahir Dar indicates significant systemic weaknesses (Table 3.6). The analysis of the sub-indicators reveals that these challenges are primarily rooted in a lack of resources, limited local autonomy, and insufficient support from higher levels of government.

Table 3.6 Institutional Capacity Sub-Indicators and RII Values

	Sub-indicator	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII
				%			
5.1	Environmental institutions capacity to coordinate environmental protection activities	6.9	38.9	39.4	14.8	0.0	**0.524**
5.2	Local-level institutions power to make decisions regarding climate change governance	21.2	39.9	26.1	12.8	0.0	**0.461**
5.3	Upper-level government support for local climate change governance initiatives	21.2	44.8	25.6	8.4	0.0	**0.442**
5.4	Environmental institutions resource to coordinate climate change governance activities	24.1	25.1	25.6	24.6	0.5	**0.504**
Overall Institutional Capacity Index							**0.483**

The capacity of environmental institutions to coordinate activities (Sub-indicator 5.1) scored the highest in this dimension (RII = 0.524), yet this only suggests a moderate perceived capacity. This is undermined by resource and personnel issues. A regional official stated that the budget "*While we receive some budget, it is often insufficient to cover the vast array of climate initiatives needed*," while a city official said, "*we have a high turnover of staff, which impacts our institutional memory.*" This underscores the difficulty in building the "long term capacities" called for in the NAP-ETH (FDRE, 2019) and aligns with the need for coordinated governance mechanisms to implement climate action plans (Koasidis et al., 2022).

A more critical issue is the lack of decision-making power at the local level (Sub-indicator 5.2), which scored a low RII of 0.461. This indicates a deficiency in local autonomy, a point confirmed by a city official who noted, "*The local institutions do try, but they don't have*

enough staff or funds to implement their plans fully." This creates a barrier for effective local action, as financial partners often cannot engage directly with municipalities that lack budgetary control (Barnard, 2015). This finding is in direct contrast to the 'multilevel governance' approach promoted by the NAP-ETH (FDRE, 2019).

The most severe weakness identified was the lack of support from upper-level government, which received the lowest RII score in this dimension (0.442). This highlights a critical disconnect between national ambitions and local realities. A district official openly stated, "*We depend on regional subsidies, which are rarely sufficient*." This misalignment between national and local plans is a known barrier to resource flows (Teshome et al., 2021) and signals a failure to implement the cross-governmental interaction mechanisms laid out in the NAP-ETH (FDRE, 2019).

Finally, the adequacy of resources for coordination with an RII of 0.504, further confirms that institutions are under-resourced. A district official explained the reality of budget allocation as "*at the district level, our main issue is funding. Most of the budget goes to agriculture and health, with little left for climate initiatives*." This chronic lack of funding severely impedes perceived institutional performance (Hermelin & Gustafsson, 2024). It also reveals a major gap between the NAP-ETH's goal of a "sustainable funding mechanism" (FDRE, 2019) and the city's poorly developed mechanisms for financing climate action.

These findings on institutional capacity are critical from both an Adaptive Governance and a Multi-Level Governance (MLG) perspective. As Adaptive Governance theory posits, capacity (in the form of financial, human, and technical resources) is the essential fuel for any adaptive action. The chronic deficits identified across all sub-indicators demonstrate that Bahir Dar's governance engine is starved of this fuel, rendering it incapable of responding effectively to climate challenges.

Furthermore, MLG theory helps to explain the root cause of this deficit. The low scores for local autonomy and support from upper-level government reveal a dysfunctional vertical relationship where mandates are devolved to the municipal level but the necessary resources and authority are not. This "unfunded mandate" is a classic MLG failure and a primary driver of the "chronic resource and capacity deficit" that paralyzes the entire UCG system. This structural problem is not merely a perception but is embedded in the regional legal framework itself. The Amhara National Regional State's Proclamation No. 245/2017, for instance, assigns municipalities like Bahir Dar the full responsibility for environmental management, land

administration, and local infrastructure development (Article 11) (Proclamation No.245/2017, 2017). However, the same proclamation simultaneously constrains their fiscal autonomy by making their power to borrow funds contingent on the "prior consent of the council of regional government" (Article 11(2) (M)). This legal structure creates the very conditions for an unfunded mandate, where the city is held responsible for solving complex climate problems but lacks the independent authority to finance the solutions.

3.3.7. Adaptability in Climate Change Governance

Adaptability, the capacity of systems and actors to respond to dynamic climate conditions, is crucial for effective governance. The Overall Adaptability Index of 0.450 for Bahir Dar is alarmingly low (Table 3.7), revealing profound weaknesses in the city's ability to adjust to climate challenges. This is most evident in difficulties to mobilize financial resources, monitor outcomes, and provide access to necessary technology.

Table 3.7 Adaptability Sub-Indicators and RII Values

	Sub-indicator	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII
				%			
6.1	Regular training opportunities on climate change adaptation and mitigation measures	9.9	35.0	29.1	25.1	1.0	**0.545**
6.2	Clearly of roles and responsibilities related to climate change response measures	8.9	34.0	28.1	28.1	1.0	**0.557**
6.3	Involved actors in climate change governance active participation in adaptation and mitigation measures	13.3	47.3	23.6	15.3	0.5	**0.485**
6.4	Flexibility of UCG plans and policies and adapt to changing climate projections	22.2	26.6	24.1	26.1	1.0	**0.514**
6.5	Effectively integration of local and indigenous climate adaptation knowledge	30.5	43.8	20.7	4.9	0.0	**0.400**
6.6	Stakeholders information and technology access needed for effective adaptation	65.5	6.9	11.3	14.8	1.5	**0.360**
6.7	Local institutions effective mechanisms for mobilizing and accessing financial resources	73.9	5.9	14.3	5.9	0.0	**0.304**
6.8	Mechanisms in place to monitor and evaluate the success of climate adaptation measures	66.5	8.9	13.8	9.4	1.5	**0.341**
6.9	The city resources and capacity to respond effectively to climate extremes	30.5	13.3	15.3	33.5	7.4	**0.548**
Overall Adaptability Index							**0.450**

The most critical failure is in mobilizing financial resources (Sub-indicator 6.7), which received the lowest score in the entire study (RII = 0.304). This signifies a high inability of local institutions to secure necessary funding. A district official confirmed this, stating, "*At the district level, our main issue is funding. Most of the budget goes to agriculture and health, with little left for climate initiatives*." This aligns with findings that financial constraints are a key

barrier to climate action in developing countries (Pertaub et al., 2024) and demonstrates a profound gap in implementing the "sustainable funding mechanisms" called for in the NAP-ETH (FDRE, 2019).

Compounding this issue is the lack of mechanisms to monitor and evaluate adaptation success (Sub-indicator 6.8), which scored an exceptionally low RII of 0.341. With over 75% of experts disagreeing or strongly disagreeing that such mechanisms exist, it is clear there is no systematic way to track progress or learn from interventions, making governance efforts unfocused. Access to technology and information (Sub-indicator 6.6) is also severely limited, with an RII of 0.360. A private sector representative highlighted the practical impact of this gap, explaining, "*We often face delays in getting permits for solar panel installations because the institutions lack the technical knowledge to process our applications efficiently*." This lack of capacity hinders climate action, a challenge also observed in Kenya where socio-economic barriers prevent technologies and information from reaching grassroots communities (Ageyo & Muchunku, 2020).

Furthermore, the integration of local and indigenous knowledge (Sub-indicator 6.5) is poor (RII = 0.400). A community member's comment, "*I know some basic things, ...but I still need guidance on modern farming techniques*," reveals a disconnect between traditional understanding and modern adaptation strategies. Overlooking valuable local knowledge is a missed opportunity and a failure to implement a key principle of the NAP-ETH (FDRE, 2019).

Other areas also show significant weakness. The active participation of actors in adaptation (Sub-indicator 6.3) is low (RII = 0.485), which stakeholders attribute to a lack of capacity. A community member observed, "*Local institutions seem to lack the resources and expertise to address climate issues effectively*." This shows that effective participation is tied to resources and power, a point also made by Lécuyer et al. (2024). Policy flexibility (Sub-indicator 6.4) also scored moderately, with an RII of 0.514, indicating that plans are not responsive to changing needs, a rigidity that can stifle investment and effective adaptation (Albrecht, 2022).

While slightly better, areas such as training opportunities (Sub-indicator 6.1, RII = 0.545) and the city's capacity to respond to extremes (Sub-indicator 6.9, RII = 0.548) are still only moderately effective. Officials noted that trainings "*lack interdisciplinary approaches*" and often overlook specific local challenges, a finding that supports the need for context-specific training (Pardoel et al., 2022). Regarding extreme events, a community member expressed low

trust, stating, "*local institutions are trying, but they are slow to respond to emergencies like flooding*," indicating a lack of preparedness (Kohlitz et al., 2019).

The highest-scoring indicator in this dimension was the clarity of roles and responsibilities (Sub-indicator 6.2, RII = 0.557). This score, which exceeds the effectiveness threshold, indicates a perception among experts that formal roles and responsibilities are defined with at least moderate clarity on paper. However, even here, a government official admitted that while inter-agency committees exist, there is "*a lack of regular meetings and follow-ups*," suggesting that formal structures do not translate into effective coordination or accountability (Addis et al., 2022).

Theoretically, the Adaptability findings reveal a governance system that has structurally failed to build the institutionalized feedback loops required by Adaptive Governance. The theory posits that effective adaptation is a learning process, but the empirical data shows a near-total absence of the necessary mechanisms. This is demonstrated by the exceptionally low RII scores for monitoring/evaluation (RII=0.341) and local financial mobilization (RII=0.304)-the two lowest scores in the entire study. This combination shows a system that is not only financially incapable of experimentation (no money for new approaches) but also incapable of learning from past actions (low monitoring and evaluation mechanisms). The failure to integrate local knowledge (RII=0.400) further closes the system off to new information. Analytically, this structural rigidity ensures the city remains locked in a reactive, vulnerable state; the profound lack of adaptive capacity is a primary mechanism that perpetuates the "chronic resource and capacity deficit." Therefore, policy must prioritize the creation of systemic learning mechanisms that make the governance framework flexible and responsive.

3.3.8. Climate Change Law and Enforcement

According to Gupta et al. (2022), effective climate governance relies on clear legal frameworks and robust enforcement. The Overall Climate Change Law and Enforcement Index for Bahir Dar is a critically low 0.400 (Table 3.8), indicating a severely inadequate legal and enforcement system. The data reveals a strong weakness at the implementation stage, where regulations, even if they exist, are not put into practice.

The most alarming finding is the miserable failure of implementation. The effective implementation of regulations (Sub-indicator 7.5) received the lowest RII score in this dimension (0.291), with over 82% of experts disagreeing that implementation is effective. A

community member's observation that "*People continue to engage in activities that harm the environment…there are no visible efforts to stop these behaviors*" clearly captures this reality. This confirms findings by Teshome et al.'s (2021) on weak enforcement in Ethiopia.

Table 3.8 Climate Change Law and Enforcement Sub-Indicators and RII Values

	Sub-indicator	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII
				%			
1	Local offices climate change governance rules and regulations in place	14.8	48.8	22.7	13.3	0.5	**0.472**
2	Awareness of the laws, regulations, and proclamations related to climate change protection	23.2	30.5	23.2	22.2	1.0	**0.495**
3	Local community regulations aligned with national climate change protection laws	29.6	45.8	20.7	3.9	0.0	**0.398**
4	Climate change protection rules and regulations easy to implement	68.0	10.3	10.8	10.3	0.5	**0.330**
5	Climate change protection regulations effective implementation	75.4	6.9	14.8	3.0	0.0	**0.291**
6	Active participation of key actors in implementing climate change protection regulations	68.5	14.3	10.3	6.9	0.0	**0.311**
7	Punishment of climate change laws violation according to legal provisions	32.5	21.2	11.8	29.6	4.9	**0.506**
Overall Climate Change Law and Enforcement Index							**0.400**

This implementation failure is worsened by the fact that the rules themselves are seen as difficult to put into practice (Sub-indicator 7.4, RII = 0.330). This difficulty was clearly expressed by a private sector representative who said the "*lack of clear guidance from the government. Sometimes, the regulations are vague, and we have to guess what is required*." This lack of regulatory clarity creates significant barriers to compliance and makes enforcement inconsistent. The difficulty of implementation is further underscored by the IPCC (2023), which notes that adaptation gaps persist globally due to slow and challenging implementation rates.

Furthermore, there is a profound lack of stakeholder participation in the implementation process itself (RII = 0.311). This score reflects a top-down approach where key actors are excluded from partnership. A CSO leader captured this dynamic, stating, "*We are often viewed as critics rather than partners, which limits our ability to contribute constructively*." This adversarial relationship prevents the co-production of effective implementation strategies, treating civil society as an observer to be managed rather than a partner to be engaged. As studies in other contexts emphasize, this lack of stakeholder participation and collaboration between government and local communities significantly undermines the perceived effectiveness of legal frameworks (Alqaisi & Almutairi, 2024).

These implementation failures stem from flawed legal frameworks upstream. There is a clear misalignment between local and national regulations (Sub-indicator 7.3, RII = 0.398), with over 75% of experts agreeing that local rules are not aligned with national laws. This lack of vertical coordination, also noted by Adom et al. (2022), undermines the consistency of governance and runs contrary to the NAP-ETH goal of 'harmonizing all policies' (FDRE, 2019). Furthermore, the existence of local rules is itself weak (Sub-indicator 7.1, RII = 0.472). Even where rules are present, a regional official admitted, "*enforcement has been challenging due to limited resources, lack of coordination across sectors, and some local governments not prioritizing environmental issues*." This points to weak institutional frameworks, a challenge highlighted by the (World Bank, 2022).

Awareness of existing laws is also poor (RII = 0.495). A district official admitted, "*Many businesses and individuals are unaware of these laws and there are few penalties for non-compliance*." This issue is worsened by practical barriers as document analysis revealed that most policies are in English, not local languages, limiting accessibility. This reflects a global trend where climte change rule awareness in developing countries is low (African Union, 2022).

Paradoxically, the perception of punishment for violations (Sub-indicator 7.7) was the highest-scoring item in this dimension (RII = 0.506), slightly crossing the ineffectiveness threshold. However, this score is condensed meaningless by the profound failures in implementation and enforcement. A community member's comment, "*There is often a lack of follow-up or consequences*," suggests that while penalties may exist on paper, they are not applied consistently, a finding that echoes reports of questionable environmental compliance in other contexts (South African Department of Forestry, 2024). This critical enforcement gap undermines the entire rule of law concerning climate governance.

The failure of this dimension, the weakest link in the entire governance chain (RII=0.400), provides a stark empirical confirmation of the central tenets of New Institutionalism. The theory posits that credible and consistently enforced rules are the bedrock of effective governance. The abysmal RII scores for effective implementation (RII=0.291) and stakeholder participation in implementation (RII=0.311) demonstrate that this bedrock is entirely absent in Bahir Dar. Analytically, this is a failure of institutional credibility. The paradox of the relatively higher score for punishment (RII=0.506) further illuminates the conflict between formal and informal institutions: while a formal rule for punishment may exist on paper, the informal

institutional norms of non-enforcement and political inertia render it meaningless in practice. This fundamental failure to establish credible "rules of the game" is the core driver of the "policy-implementation chasm," and is the ultimate reason for the UCG system's overall ineffectiveness. Therefore, policy interventions must structurally mandate a dedicated enforcement body to restore the credibility of the formal institutional framework.

3.3.9. Inferential Analysis and Perceptual Gaps across Governance Levels

To identify potential differences in perception among the experts sampled from different administrative levels, a series of one-way ANOVAs were conducted. The analysis revealed a high degree of consensus on six of the seven UCG dimensions, with no statistically significant differences found. However, a statistically significant difference was identified among the groups for the dimension of Awareness-Raising ($F(2, 159) = 3.392$, $p = .036$). This finding suggests a specific and important perceptual gap between officials working at different scales of governance. The full ANOVA results are summarized in Table 3.9.

Table 3.9 ANOVA Results for UCG Dimensions by Administrative Level

UCG Dimension	F-statistic (df)	p-value
Accountability	2.145 (2, 159)	.120
Participation	0.083 (2, 159)	.921
Equity	0.867 (2, 159)	.422
Awareness-Raising	3.392 (2, 159)	.036*
Institutional Capacity	1.036 (2, 159)	.357
Adaptability	1.820 (2, 159)	.165
Climate Change Law and Enforcement	0.716 (2, 159)	.490

*Note: $p < .05$.

A Tukey HSD post-hoc test conducted on the Awareness-Raising index provided further insight into this discrepancy. The results indicated that the mean score for regional experts ($M = 0.53$, $SD = 0.09$) was significantly higher than for both city-level experts ($M = 0.48$, $SD = 0.08$, $p = .038$) and sub-city experts ($M = 0.48$, $SD = 0.08$, $p = .042$). The perceptions of city and sub-city experts did not significantly differ from each other ($p = .883$). This finding provides statistical evidence of a vertical disconnect, where officials at the highest administrative tier view awareness-raising efforts more favorably than those working at the local implementation levels. This statistically significant divergence ($p<.05$) serves as the primary quantitative validation of the "policy-implementation gap," confirming that perceptions of governance success weaken as one moves closer to the ground-level reality of implementation.

3.3.10. Overall Effectiveness of UCG in Bahir Dar

This study evaluated the perceived effectiveness of UCG in Bahir Dar City across seven key dimensions. The findings, derived from a composite index and supported by rich qualitative data, reveal a governance system that is fundamentally ill-equipped to handle the escalating pressures of urbanization and climate change. With an Overall UCG Index of 0.489 (Table 3.10), the current framework is demonstrably ineffective, falling significantly short of the strategic priorities for resilience and adaptation outlined in NAP-ETH (FDRE, 2019).

Table 3.10 Bahir Dar City UCG Effectiveness Index

	Index	RII
1	Accountability	0.639
2	Participation	0.485
3	Equity	0.483
4	Awareness-Raising	0.488
5	Institutional Capacity	0.483
6	Adaptability	0.450
7	Climate Change Law and Enforcement	0.400
Overall UCG Index		**0.489**

Accountability emerged as the only dimension to surpass the 0.50 effectiveness threshold, representing a relative strength. However, this moderate score is fragile. Qualitative data exposed a critical disconnect between policy and practice, with insufficient budgetary oversight and weak local-level enforcement undermining formal accountability structures.

In contrast, every other dimension of governance were found to be inadequate. Participation is largely superficial, with stakeholders often treated as passive implementers rather than active partners in planning. This superficial approach prevents the incorporation of diverse perspectives and fails to achieve the genuine “stakeholder empowerment” envisioned by the NAP-ETH. Similarly, Equity is compromised by systemic barriers that exclude marginalized groups from decision-making and the benefits of climate action, leaving the most vulnerable populations at heightened risk.

Awareness-Raising efforts are ineffective, with campaigns that are neither tailored to local contexts nor successful in translating general information into actionable knowledge for communities. This is mirrored by the low score for Institutional Capacity (RII = 0.483), which underscores how governance structures are constrained by inadequate resources, limited local autonomy, and poor inter-agency coordination. The system's ability to evolve is severely

constrained, as shown by the Adaptability score of 0.450. The governance framework is rigid, failing to integrate local knowledge, mobilize necessary resources, or create flexible policies capable of responding to dynamic climate realities.

The most critical failure lies in Climate Change Law and Enforcement, which, with an RII of 0.400, is the weakest link in the entire governance chain. This dimension suffers from a systemic failure at the implementation stage, laws are poorly understood, inconsistently applied, and backed by no credible threat of penalties, rendering the legal framework ineffective.

Significantly, this overall assessment of widespread ineffectiveness was largely shared by experts across all levels of government. The ANOVA results showed no significant differences in perception for six of the seven dimensions. However, the one exception to this consensus, the statistically significant perceptual gap identified for Awareness Raising (p=.036), provides powerful quantitative evidence for the "policy-implementation chasm" that qualitative data also revealed. This vertical disconnect, where regional officials view efforts more favorably than their local counterparts, is a key characteristic of the systemic dysfunction.

Generally, the UCG system in Bahir Dar is a chain with multiple broken links. While accountability mechanisms show some promise, they are fundamentally undermined by profound weaknesses across all other areas. The systemic lack of meaningful participation, equity, institutional capacity, and adaptability compounded by strong weaknesses in legal enforcement creates a governance structure incapable of delivering effective climate action. These findings demand transformative change, moving beyond incremental adjustments to a comprehensive service of the governance system. Achieving climate resilience in Bahir Dar requires an integrated approach that urgently aligns local actions with the strategic priorities of the NAP-ETH, prioritizing robust legal frameworks, genuine stakeholder empowerment, and equitable community engagement.

3.4. Conclusions and Policy Recommendations

3.4.1. Synthesizing the Governance Deficit in Bahir Dar

Addressing the study's primary objective to evaluate institutional effectiveness, the analysis reveals that Bahir Dar's UCG framework is not merely underperforming but suffers from systemic and interconnected failures. The core results are synthesized in Table 3.11, which demonstrates that the system is fundamentally ill-equipped to handle the escalating pressures of urbanization and climate change. The Overall UCG Index of 0.489, which falls below the

0.50 agreement threshold, validates the conclusion that the governance system is ineffective. Beyond the descriptive scores, three overarching causal mechanisms of failure emerge from the analysis.

First, a "Capacity-to-Enforcement Failure Loop" creates a profound "policy-implementation chasm." Crucially, this analysis clarifies that the primary governance failure in Bahir Dar is not one of institutional design, as formal mandates and environmental regulations largely exist, but of implementation. The evidence indicates that weak Institutional Capacity directly prevents effective Law and Enforcement. This lack of enforcement, in turn, renders accountability meaningless, creating a self-reinforcing cycle of institutional paralysis. This vertical disconnect is not only a qualitative finding but is now statistically evidenced by the significant perceptual gap identified via ANOVA (p=.036) between regional policymakers and local-level implementers regarding awareness campaigns. This chasm mirrors trends in cities like Accra and Kampala, where national ambitions falter due to local enforcement gaps (African Union, 2022; UN-Habitat, 2022). By contrast, the success of environmental enforcement in cities like Medellín, Colombia, demonstrates that closing this chasm requires strong mayoral leadership and dedicated enforcement units (Serrat, 2025), elements notably absent in Bahir Dar.

Table 3.11 Synthesis of UCG Effectiveness and Key Evidence

UCG Dimension	**RII Score**	**Key Finding**	**Evidence of Structural Failure**
Accountability	0.639	Relative Strength (Above 0.50 threshold)	Undermined by Informal Institutions (Political/Bureaucratic inertia).
Participation	0.485	Ineffective (Consensus of Disagreement)	Failure to build Polycentric System; tokenistic "invited spaces" (Qualitative Data).
Equity	0.483	Deficient (Consensus of Disagreement)	Systemic failure of Procedural & Distributive Justice; marginalization confirmed by low RII scores for access (0.388) and inclusion (0.387).
Awareness-Raising	0.488	Ineffective (Below 0.50 threshold)	Statistically Proven Vertical Disconnect; Regional vs. Local perceptions differ significantly (ANOVA p=0.036).
Institutional Capacity	0.483	Deficient (Below 0.50 threshold)	Chronic Resource Deficit (inputs of budget/staff are insufficient).
Adaptability	0.450	Critically Low (Consensus of Disagreement)	Absence of Institutionalized Feedback Loops; Monitoring (0.341) and Financial Mobilization (0.304) are the weakest links.
Climate Change Law & Enforcement	0.400	Total Failure (Lowest Score)	Implementation Chasm; Rules are unenforced, rendering Accountability meaningless.

Second, the governance model suffers from a "Financial Paralysis Trap," which acts as the causal root of the resource deficit. The critically low scores for financial mobilization (RII=0.304) are not isolated problems; they starve the entire system. Without adequate funding, local institutions cannot enforce laws or engage communities, trapping them in a cycle of reactive governance. This mechanism explains the failure of adaptability; without resources, there is no room for experimentation. This financial bottleneck mirrors findings from the Coalition for Urban Transitions (2021) regarding secondary cities across Africa and Asia. However, emerging models from the Global South offer a counter-narrative; cities like Mexico City and Pune, India, have successfully leveraged municipal green bonds to break this trap (FSD Africa, 2025; Herrera, 2024), highlighting a specific financing mechanism gap in Bahir Dar's current structure.

Finally, an "Exclusion-to-Mistrust Spiral" explains the superficial approach to stakeholder engagement. Driven by a top-down political economy, the low scores for Participation (RII=0.485) and Equity (RII=0.483) prevent the integration of valuable local knowledge, which causally undermines Adaptability. This phenomenon of "invited spaces," where participation is tokenistic, has been observed from Dhaka to Durban (Alam, 2018). This stands in stark contrast to the institutionalized co-production models seen in Porto Alegre, Brazil, where participatory budgeting created a structural mandate for citizen influence (Baiocchi & Ganuza, 2017). Ultimately, the lack of such genuine partnership structures in Bahir Dar hinders the co-production of lasting climate solutions.

This study's findings hold significant theoretical implications. The failure of Law and Enforcement in Bahir Dar provides a stark empirical confirmation of the central tenets of New Institutionalism; without credible rules and consequences, governance systems fail. Similarly, the superficial nature of participation highlights a key challenge for Collaborative Governance theory in contexts with significant power imbalances. The city's inability to mobilize resources and learn from experience underscores the practical barriers to achieving the ideals of Adaptive Governance. By empirically grounding these mainstream theories in a Global South context, this study contributes to a more nuanced understanding of the challenges and context-specific barriers to effective UCG.

3.4.2. Policy Recommendations

Addressing the systemic failures identified in this study requires a strategic overhaul. Moving beyond broad ambitions, we propose targeted recommendations for policymakers in Bahir Dar

and comparable secondary cities, explicitly linked to the empirical weaknesses diagnosed in the analysis.

1. Bridging the Policy-Implementation Gap (Enforcement & Accountability)

Directly responding to the critical failure of the Law and Enforcement dimension (RII=0.400), the priority must shift from designing new policies to enforcing existing ones. This study recommend establishing a Municipal Climate Enforcement Unit, a dedicated body with the specific mandate to monitor compliance and issue penalties. Furthermore, to address the qualitative findings regarding opaque financial management despite moderate audit scores, the city should implement a public-facing budget-tracking portal. This allows CSOs to monitor climate expenditure, operationalizing financial accountability.

2. Addressing the Resource Deficit (Capacity & Adaptability)

To address the financial paralysis indicated by the study's lowest scoring sub-indicator (Resource Mobilization, RII=0.304), structural changes to municipal financing are essential. The study recommend mandating a Climate Action Budgetary Earmark, legislating a required minimum percentage of the city budget to ensure predictable funding for adaptation projects. This financial commitment must be paired with a continuous Local Government Capacity-Building Program, partnered with regional universities, to address the specific skill gaps identified in the institutional capacity analysis.

3. Overcoming Superficial Engagement (Participation & Equity)

Countering the tokenism evidenced by the low Participation score (RII=0.485) and Equity score (RII=0.483), governance processes must be re-engineered. The study recommend moving to a model of mandated co-production, where all new climate projects require a steering committee with empowered community representatives. To decentralize planning, the city should create Ward-Level Climate Adaptation Forums with dedicated seed funding, directly addressing the equity deficit by empowering local communities to identify risks and solutions.

4. Regional Governance Implications

The findings offer critical perspectives for the Amhara Regional Government. The significant "policy-implementation chasm," now statistically validated by the perceptual gap between

regional and local officials regarding awareness (p=.036), implies the region must move from policy formulation to implementation support. This study recommend the region establish a dedicated Urban Climate Resilience Support Unit for secondary cities and create performance-based climate grants to incentivize local enforcement. Crucially, the region should use the statistically proven perceptual gap on issues like awareness-raising as a diagnostic tool to identify and address breakdowns in vertical coordination.

Finally, this study makes a clear and specific contribution to the existing literature on UCG. While building on the methodological foundations of prior governance indices in Ethiopia (e.g., Addis et al., 2022; Assele, 2019), this study offers three advancements. Methodologically, it enhances the index approach with a more robust theoretical grounding and the integration of inferential statistics (ANOVA) to empirically validate systemic disconnects. Empirically, it provides the an in-depth UCG assessment for a regional city, generating findings that are more representative of the typical urbanization challenges across the Global South than studies focused on capital cities. Theoretically, by grounding mainstream governance theories in this context, it illuminates the specific, on-the-ground barriers that prevent the realization of these theoretical models in practice. By offering this refined diagnostic framework and its transferable insights, it provides a valuable tool for both scholars and policymakers striving to build climate resilience in the world's fastest-growing urban centers.

3.4.3. Limitations and Future Directions

The contributions of this study are presented alongside an acknowledgment of the necessary methodological trade-offs, which define clear avenues for future research.

First, the research design prioritized depth over breadth. While this choice allowed for an unparalleled diagnosis of the internal systemic mechanisms, it does not provide a direct statistical benchmark against comparable cities, nor does it capture institutional evolution over time. Future research should therefore focus on comparative case studies and longitudinal investigation to test the broader applicability of the identified structural failures and track the impact of the reforms proposed herein.

Second, the primary data utilized was carefully scoped to diagnose the governance process itself. The choice to focus the main quantitative assessment on government expert perceptions (N=162) was a deliberate strategic decision to obtain an informed internal diagnostic of institutional functionality. We have explicitly mitigated the potential for "insider bias" by

ensuring a robust qualitative triangulation with non-state actors. Future research could complement this internal view with a randomized household survey to quantitatively assess grassroots perceptions of UCG outcomes.

By addressing these critical future research directions, a more dynamic and multi-perspective understanding of the challenges of building climate resilience in the Global South can be achieved.

REFRENCES

Abebe, M. G. (2024). Impacts of urbanization on food security in Ethiopia. A review with empirical evidence. *Journal of Agriculture and Food Research*, *15*(January), 100997. https://doi.org/10.1016/j.jafr.2024.100997

Addis, T. L. (2023). Climate Change Governance in Addis Ababa City Administration, Ethiopia. In *Dissertation*. Addis Ababa University.

Addis, T. L., Birhanu, B. S., & Italemahu, T. Z. (2022). Effectiveness of Urban Climate Change Governance in Addis Ababa City, Ethiopia. *Urban Science*, *6*(3). https://doi.org/10.3390/urbansci6030064

Adigeh, D. T., & Abebe, B. G. (2023). The Practice of Peri-Urban Land Acquisition by Expropriation for Housing Purposes and the Implications: The Case of Bahir Dar, Ethiopia. *Urban Science*, *7*(2). https://doi.org/10.3390/urbansci7020041

Adom, R. K., Simatele, M. D., & Reid, M. (2022). Addressing the challenges of water-energy-food nexus programme in the context of sustainable development and climate change in South Africa. *Journal of Water and Climate Change*, *13*(7). https://doi.org/10.2166/wcc.2022.099

African Union. (2022). African Union Climate Change and Resilient Development Strategy and Action Plan. *African Union*.

Ageyo, J., & Muchunku, I. G. (2020). Beyond the Right of Access: A Critique of the Legalist Approach to Dissemination of Climate Change Information in Kenya. *Sustainability 2020, Vol. 12, Page 2530*, *12*(6), 2530. https://doi.org/10.3390/SU12062530

Aggarwal, J., Shukla, N., Prasad, S., & Bhasin, S. (2022). Strengthening Climate Accountability: Improving Compliance and Delivery under the Paris Agreement Strengthening Climate Accountability. *COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)*.

Alam, D. (2018). *Open Spaces in Dhaka: The Encroachment and A way to Reclaim*. Conference Paper. https://www.researchgate.net/publication/341785262_Open_Spaces_in_Dhaka_The_Encroachment_and_A_way_to_Reclaim

Albrecht, J. (Ed.). (2022). *Instruments for Climate Policy: Limited versus Unlimited Flexibility (New Horizons in Environmental Economics series)*. Edward Elgar

Publishing. https://www.amazon.com/Instruments-Climate-Policy-Flexibility-Environmental/dp/1840647590?utm_source

Alizadeh, O. (2023). Changes in the mean and variability of temperature and precipitation over global land areas. *Environmental Research: Climate*, *2*(3), 035006. https://doi.org/10.1088/2752-5295/ACE279

Almazroui, M., Saeed, F., Saeed, S., Nazrul Islam, M., Ismail, M., Klutse, N. A. B., & Siddiqui, M. H. (2020). Projected Change in Temperature and Precipitation Over Africa from CMIP6. *Earth Systems and Environment*, *4*(3), 455–475. https://doi.org/10.1007/S41748-020-00161-X/FIGURES/14

Almulhim, A. I., Bibri, S. E., Sharifi, A., Ahmad, S., & Almatar, K. M. (2022). Emerging Trends and Knowledge Structures of Urbanization and Environmental Sustainability: A Regional Perspective. *Sustainability, MDPI*, *14*(20), 13195. https://doi.org/10.3390/SU142013195

Alqaisi, A. F. R., & Almutairi, F. N. (2024). Assessing the Gap between Environmental Legislation and Effective Implementation: A Study and Guidelines for Enhancing the Implementation Performance of Environmental Laws. *J. Electrical Systems*, *20*(7), 937–947.

Aminpour, P., Gray, S. A., Beck, M. W., Furman, K. L., Tsakiri, I., Gittman, R. K., Grabowski, J. H., Helgeson, J., Josephs, L., Ruth, M., & Scyphers, S. B. (2022). Urbanized knowledge syndrome-erosion of diversity and systems thinking in urbanites' mental models. *Urban Sustainability*. https://doi.org/10.1038/s42949-022-00054-0

Appelhans, N. (2017). Urban Planning and Everyday Urbanisation A Case Study on Bahir Dar, Ethiopia. In *Dissertation*. https://doi.org/10.1515/9783839437155

Arnstein, S. R. (2019). A Ladder of Citizen Participation. *Journal of the American Planning Association*, *85*(1), 24–34. https://doi.org/10.1080/01944363.2018.1559388

Asmamaw, M., & Debie, E. (2023). Characterizing groundwater quality for a safe supply of water using WQI and GIS in Bahir Dar city, northwest Ethiopia. *Water Practice and Technology*, *18*(4), 859–883. https://doi.org/10.2166/wpt.2023.046

Assele, A. A. (2019). The Political Economy of Environmental Governance in Ethiopia: Exploring Trends, Actors and Drivers. In *Dissertation* (Issue April). Addis Ababa University.

Averchenkova, A., Catherine Higham, & Isabela Keuschnigg. (2024). *Impacts of climate framework laws Lessons from Germany, Ireland and New Zealand*. www.lse.ac.uk/granthaminstitute/

Azman, N. S., Ramli, M. Z., Razman, R., Zawawi, M. H., Ismail, I. N., & Isa, M. R. (2019). Relative importance index (RII) in ranking of quality factors on industrialised building system (IBS) projects in Malaysia. *AIP Conference Proceedings*, *2129*(020029). https://doi.org/10.1063/1.5118037

Babbie, E. (2013). The Practice of Social Research. In *Proceedings of the National Academy of Sciences* (Thirteenth). Cengage Learning.

http://dx.doi.org/10.1016/j.bpj.2015.06.056%0A

Bahir Dar City Structural Plan Preparation Project Office. (2020). *Population Study Report*.

Baiocchi, G., & Ganuza, E. (2017). Popular Democracy : The Paradox of Participation. In *Stanford University Press*. Stanford University Press. https://books.google.com/books/about/Popular_Democracy.html?id=zNK1DQAAQBAJ

Barnard, S. (2015). *Climate finance for cities How can international climate funds best support low-carbon and climate resilient urban development?* www.odi.org/twitter

Berry, B. J. L. (2008). Urbanization. In *Urban Ecology*. springer.

Beyene, E., Adam, A. G., & Minale, A. S. (2023). Examining the practice of urban governance using UN-Habitat urban governance index in Gondar city, North West Ethiopia. *Cogent Social Sciences*, *9*(1). https://doi.org/10.1080/23311886.2023.2208934

Biko, S. (2024). 2021/22 National Environmental Compliance and Enforcement Report (NECER). In *Department of Forestry, Fisheries and the Environment*. https://www.dffe.gov.za/2021/22-National-Environmental-Compliance-and-Enforcement-Report-%28NECER%29-shows-questionable-environmental-compliance-across-many-regulated-sectors?

Birara, H., Pandey, R. P., & Mishra, S. K. (2020). Projections of future rainfall and temperature using statistical downscaling techniques in Tana Basin, Ethiopia. *Sustainable Water Resources Management*, *6*(5), 1–17. https://doi.org/10.1007/S40899-020-00436-1/FIGURES/9

Blackburn, S., Pelling, M., & Marques, C. (2019). Megacities and the Coast: Global Context and Scope for Transformation. *Coasts and Estuaries: The Future*, 661–669. https://doi.org/10.1016/B978-0-12-814003-1.00038-1

Brenner, N. (2013). Theses on Urbanization. *Public Culture*, *25*(1 (69)), 85–114. https://doi.org/10.1215/08992363-1890477

Casado-Asensio, J., Blaquier, D., & Sedemund, J. (2022). *Strengthening Capacity For Climate Action In Developing Countries: Overview And Recommendations*.

Castán-Broto, V. (2020). Climate change politics and the urban contexts of messy governmentalities. *Territory, Politics, Governance*, *8*(2), 241–258. https://doi.org/10.1080/21622671.2019.1632220;WGROUP:STRING:PUBLICATION

Castán-Broto, V., & Westman, L. K. (2020). Ten years after Copenhagen: Reimagining climate change governance in urban areas. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(4), e643. https://doi.org/10.1002/WCC.643

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society, Published Online: Sep 30, 2014 | Doi:10.5751/ES-06824-190356*, *19*(3). https://doi.org/10.5751/ES-06824-190356

Cohen, B. (2004). Urban Growth in Developing Countries: A Review of Current Trends and a Caution Regarding Existing Forecasts. *World Development*, *32*(1), 23–51.

https://doi.org/10.1016/J.WORLDDEV.2003.04.008

CSA. (1984). The 1984 Population and Housing Census of Ethiopia. In *Central Statistical Authority* (Issue December). http://www.csa.gov.et/surveys/Population and Housing census/ETH-pop-2007/survey0/data/Doc/Reports/National_Statistical.pdf

CSA. (1995). Transitional Government of Ethiopia Office of the Population and Housing Census Commission the 1994 Population and Housing Census of Ethiopia Analytical Report At Addis Ababa Level.Volume 1 Statistical Report. *Central Statistical Authority*.

CSA. (2007). Population and Housing Census 2007 Report. In *Central Statistical Agency, Addis Ababa*. http://www.csa.gov.et/surveys/Population and Housing census/ETH-pop-2007/survey0/data/Doc/Reports/National_Statistical.pdf

CSA. (2013). Population Projection of Ethiopia for All Regions At Woreda Level from 2014-2017. In *Central Statistical Agency (CSA)* (Issue August 2013).

CSA. (2018). Statistical report on the 2018 urban Employment Unemployment survey. *Central Statistical Agency, Ethiopia, October*, 301.

Darjee, K. B., Neupane, P. R., & Köhl, M. (2023). Proactive Adaptation Responses by Vulnerable Communities to Climate Change Impacts. *Sustainability (Switzerland)*, *15*(14), 10952. https://doi.org/10.3390/SU151410952/S1

Digafe, B. M., Adam, A. G., & Shibeshi, G. B. (2024). Evaluation of the urban Land use plan's effectiveness in achieving resource efficiency: the case of Bahir Dar city-Ethiopia. *International Journal of Urban Sustainable Development*, *16*(1), 17–34. https://doi.org/10.1080/19463138.2024.2303503

Dodman, D., Hayward, B., Pelling, M., Broto, V. C., & Chow, W. T. L. (2022). *Cities, settlements and key infrastructure*. 907–1040.

Echeverri, L. G., Bustamante, M., Jun, M., & Rafa, N. (2024). *Seeking Synergy Solutions: Integrating Climate and SDG Knowledge and Data for Action*. https://pure.iiasa.ac.at/id/eprint/19810/1/Thematic Report on Knowledge and Data-061024.pdf

Egan, P. J., & Mullin, M. (2024). US Partisan Polarization on Climate Change: Can Stalemate Give Way to Opportunity? *PS: Political Science & Politics*, *57*(1), 30–35. https://doi.org/10.1017/S1049096523000495

FDRE. (2019). *Ethiopia's Climate Resilient Green Economy Strategy. National Adaptation Plan* (Issue May).

Freitas, A. S., Mwaniki, G., & Baumgartner, L. (2024). Climate Finance in Africa. In *UNDP*.

FSD Africa. (2025). *Impact of Green Bonds In Africa*.

Furnaro, A., & Kay, K. (2022). Labor resistance and municipal power: Scalar mismatch in the Los Angeles Green New Deal. *Political Geography*, *98*, 102684. https://doi.org/10.1016/J.POLGEO.2022.102684

Gaventa, J. (2006). Finding the Spaces for Change: A Power Analysis. *IDS Bulletin*, *37*(6), 23–33. https://doi.org/10.1111/J.1759-5436.2006.TB00320.X

Getachew, B., & Manjunatha, B. R. (2021). Climate change projections and trends simulated from the CMIP5 models for the Lake Tana sub-basin, the Upper Blue Nile (Abay) River Basin, Ethiopia. *Environmental Challenges*, *5*, 100385. https://doi.org/10.1016/J.ENVC.2021.100385

Getu, K., & Gangadhara Bhat, H. (2024). Application of geospatial techniques and binary logistic regression model for analyzing driving factors of urban growth in Bahir Dar city, Ethiopia. *Heliyon*, *10*(3), e25137. https://doi.org/10.1016/j.heliyon.2024.e25137

Guerzovich, F., & Wadeson, A. (2024). Scaling Up Collaborative Social Accountability in Complex Governance Systems: A Relational Approach for Evidencing Sustainability. *The World Bank Group*. https://doi.org/10.1596/41061

Gupta, A., Konrad, S., & van Deursen, M. (2022). Capacity building for climate transparency: neutral 'means of implementation' or generating political effects? *Climate Policy*, *22*(5), 557–575. https://doi.org/10.1080/14693062.2021.1986364

Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia. *Landscape and Urban Planning*, *106*(2), 149–157. https://doi.org/10.1016/j.landurbplan.2012.02.016

Henderson, J. V. (2005). Urbanization and Growth. *Handbook of Economic Growth*, *1*(SUPPL. PART B), 1543–1591. https://doi.org/10.1016/S1574-0684(05)01024-5

Hermelin, B., & Gustafsson, S. (2024). A local governance initiative for climate mitigation: the place-leading role of local government. *Regional Studies, Regional Science*, *11*(1), 599–613. https://doi.org/10.1080/21681376.2024.2401550

Herrera, H. (2024). The proliferation of municipal green bonds in Africa and Latin America: the need for a climate justice approach. *Environment & Urbanization*, *36*(1), 147–172. https://journals.sagepub.com/doi/pdf/10.1177/09562478241230290

Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2019). Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. *Regional Environmental Change*, *12*, 791–805. https://doi.org/10.1007/s10113-018-1329-3

Hügel, S., & Davies, A. R. (2020). Public participation, engagement, and climate change adaptation: A review of the research literature. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(4), e645. https://doi.org/10.1002/WCC.645

Hughes, S., Giest, S., & Tozer, L. (2020). Accountability and data-driven urban climate governance. *Nature Climate Change*, *10*(12), 1085–1090. https://doi.org/10.1038/S41558-020-00953-Z

IPCC. (2022a). Climate Change 2022: Impacts, Adaptation and Vulnerability. In *IPCC Sixth Assessment*. https://www.ipcc.ch/report/ar6/wg2/

IPCC. (2022b). IPCC, 2022: Summary for Policy Makers. *Climate Change 2022: Impacts, Adaptation and Vulnerability*, 1–40. www.ipcc.ch

IPCC. (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Repor. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *IPCC*. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Jordan, A. (2018). Governing Climate Change: Polycentricity in Action? *Governing Climate Change*. https://doi.org/10.1017/9781108284646

Keenan, J. M., Chu, E., & Peterson, J. (2019). From funding to financing: perspectives shaping a research agenda for investment in urban climate adaptation. *International Journal of Urban Sustainable Development*, *11*(3), 297–308. https://doi.org/10.1080/19463138.2019.1565413;REQUESTEDJOURNAL:JOURNAL:TJUE20;WGROUP:STRING:PUBLICATION

Khatibi, F. S., Dedekorkut-Howes, A., Howes, M., & Torabi, E. (2021). Can public awareness, knowledge and engagement improve climate change adaptation policies? *Discover Sustainability*, *2*(1), 1–24. https://doi.org/10.1007/S43621-021-00024-Z/FIGURES/5

Klein, J., Araos, M., Karimo, A., Heikkinen, M., Ylä-Anttila, T., & Juhola, S. (2018). The role of the private sector and citizens in urban climate change adaptation: Evidence from a global assessment of large cities. *Global Environmental Change*, *53*, 127–136. https://doi.org/10.1016/J.GLOENVCHA.2018.09.012

Koasidis, K., Nikas, A., Karamaneas, A., Saulo, M., Tsipouridis, I., Campagnolo, L., Gambhir, A., Van De Ven, D.-J., Mcwilliams, B., & Doukas, H. (2022). Climate and sustainability co-governance in Kenya: A multi-criteria analysis of stakeholders' perceptions and consensus. *Energy for Sustainable Development*, *68*, 457–471. https://doi.org/10.1016/j.esd.2022.05.003

Kohlitz, J., Chong, J., & Willetts, J. (2019). Analysing the capacity to respond to climate change: a framework for community-managed water services. *Climate and Development*, *11*(9), 775–785. https://doi.org/10.1080/17565529.2018.1562867

Kuma, G. H., Fufa Feyessa, F., & Adugna Demissie, T. (2022). Local climate change indications: Historical trends, multi-model projections and implications in Bilate Catchment, Southern Ethiopia. *IOP Conference Series: Earth and Environmental Science*, *1016*(1). https://doi.org/10.1088/1755-1315/1016/1/012030

Lécuyer, L., Balian, E., Butler, J. R. A., Barnaud, C., Calla, S., Locatelli, B., Newig, J., Pettit, J., Pound, D., Quétier, F., Salvatori, V., Von Korff, Y., & Young, J. C. (2024). The importance of understanding the multiple dimensions of power in stakeholder participation for effective biodiversity conservation. *People and Nature*, *6*(4), 1407–1420. https://doi.org/10.1002/PAN3.10672

Li, Z., Xu, Y., Sun, Y., Wu, M., & Zhao, B. (2020). Urbanization-Driven Changes in Land-Climate Dynamics: A Case Study of Haihe River Basin, China. *Remote Sensing*, *12*(17), 2701. https://doi.org/10.3390/RS12172701

Menashe, A., & Bocquier, P. (2021). Urbanization Is No Longer Driven by Migration in Low- and Middle-Income Countries (1985–2015). *Population and Development Review*, *47*(3), 639–663. https://doi.org/10.1111/PADR.12407

Nabatchi, T., & Emerson, K. (2023). Collaborative Governance Regimes. *Collaborative Governance Regimes*. https://doi.org/10.1353/BOOK44406

Nannawo, A. S., Kumar Lohani, T., & Eshete, A. A. (2017). Envisaging the actual evapotranspiration and elucidating its effects under climate change scenarios on agrarian lands of bilate river basin in Ethiopia. *Heliyon*, *8*(e10368). https://doi.org/10.1016/j.heliyon.2022.e10368

North, D. C. (1990). Institutions, Institutional Change and Economic Performance. *Institutions, Institutional Change and Economic Performance*. https://doi.org/10.1017/CBO9780511808678

Ofoegbu, C., Chirwa, P. W., Francis, J., & Babalola, F. D. (2019). Assessing local-level forest use and management capacity as a climate-change adaptation strategy in Vhembe district of South Africa. *Climate and Development*, *11*(6), 501–512. https://doi.org/10.1080/17565529.2018.1447904

Orkodjo, T. P., Kranjac-Berisavijevic, G., & Abagale, F. K. (2022). Impact of climate change on future precipitation amounts, seasonal distribution, and streamflow in the Omo-Gibe basin, Ethiopia. *Heliyon*, *8*(6), e09711. https://doi.org/10.1016/j.heliyon.2022.e09711

Pande, C. B., Moharir, K. N., Varade, A. M., Abdo, H. G., Mulla, S., & Yaseen, Z. M. (2023). Intertwined Impacts Of Urbanization And Land Cover Change On Urban Climate And Agriculture In Aurangabad City (MS), India Using Google Earth Engine Platform. *Journal of Cleaner Production*, *422*, 138541. https://doi.org/10.1016/J.JCLEPRO.2023.138541

Pardoel, Z. E., Reijneveld, S. A., Postma, M. J., Lensink, R., Koot, J. A. R., Swe, K. H., Van Nguyen, M., Pamungkasari, E. P., Tenkink, L., Vervoort, J. P. M., & Landsman, J. A. (2022). A Guideline for Contextual Adaptation of Community-Based Health Interventions. *International Journal of Environmental Research and Public Health*, *19*(10), 5790. https://doi.org/10.3390/IJERPH19105790/S1

Pertaub, D.-P., Crick, F., Greene, S., Mengistie, T., Gizaw, S., Nebsu, B., & Alemayehu, M. (2024). *Climate change; Policy and planning Piloting climate-smart development planning for local government in Ethiopia Lessons learned from the BRE programme*. www.iied.org

Petkovic, A., & Rahman, T. (2021). Government Accountability and Development: Evidence from Young Democracies. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.3971900

Prabin, M. (2024). *Multilevel Governance For Climate Change Mitigation And Adaptation*. United Nations Department of Economic and Social Affairs.

Raihan, A. (2023). A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, *2*(3), 36–58. https://doi.org/10.56556/jescae.v2i3.587

Roberts, E., & Pelling, M. (2018). Climate change-related loss and damage: translating the global policy agenda for national policy processes. *Climate and Development*, *10*(1), 4–

17. https://doi.org/10.1080/17565529.2016.1184608

Roy, S. (2021). URBANISATION IN BANGLADESH: CHALLENGES AND WAY FORWARD. *Asia-Europe Foundation (ASEF)*. https://asef.org/wp-content/uploads/2021/11/ASEFSU23-Background-Paper_Sustainable-Urbanisation-in-Bangladesh-Dhaka.pdf

Serrat, O. (2025). Localizing Climate Action in Latin American and Caribbean Cities. *Anthropogenic Solutions for Climate Change*, 51–67. https://doi.org/10.1007/978-981-96-8654-4_7

Seyoum, S. (2014). The Growth of Bahir Dar: 1941-1974. *Ethiopian Journal of Development Research*, *36*(2), 83–109.

Smith, M. D., & Wodajo, T. (2022). New Perspectives on Climate Equity and Environmental Justice. *Bulletin of the American Meteorological Society*, *103*(6), E1522–E1530. https://doi.org/10.1175/BAMS-D-22-0032.1

Solorio, I. (2021). Leader on paper, laggard in practice: policy fragmentation and the multi-level paralysis in implementation of the Mexican Climate Act. *Climate Policy*, *21*(9), 1175–1189. https://doi.org/10.1080/14693062.2021.1894084

Stock, R., Vij, S., & Ishtiaque, A. (2021). Powering and puzzling: climate change adaptation policies in Bangladesh and India. *Environment, Development and Sustainability*, *23*(2), 2314–2336. https://doi.org/10.1007/S10668-020-00676-3/FIGURES/1

Sultana, F. (2022). Critical climate justice. *Geographical Journal*, *188*(1), 118–124. https://doi.org/10.1111/GEOJ.12417

Tashakkori, A., & Teddlie, C. (2003). Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International Journal of Social Research Methodology*, *6*(1), 61–77. https://doi.org/10.1080/13645570305055

Teshome, H., Tesfaye, K., Dechassa, N., Tana, T., & Huber, M. (2021). Analysis of Past and Projected Trends of Rainfall and Temperature Parameters in Eastern and Western Hararghe Zones, Ethiopia. *Atmosphere 2022, Vol. 13, Page 67*, *13*(1), 67. https://doi.org/10.3390/ATMOS13010067

Tessema, M. W. (2017). Impact of Urban Expansion on Surrounding Peasant Land the Case of Boloso Sore Woreda, Areka Town, SNNPR, Ethiopia. *Global Journal of Human-Social Science*, *17*(2), 1–15.

Tholibon, D. A., Md Nujid, M., Mokhtar, H., Rahim, J. A., Aziz, N. F. A., & Tarmizi, A. A. A. (2021). Relative Importance Index (RII) In Ranking the Factors of Employer Satisfaction Towards Industrial Training Students. *International Journal of Asian Education*, *2*(4), 493–503. https://doi.org/10.46966/ijae.v2i4.187

UN-Habitat. (2004). Urban Governance Index: Conceptual Foundation and Field Test Report. In P. Taylor & M. Halfani (Eds.), *UN-Habitat* (Issue August). papers3://publication/uuid/4B833808-137D-4037-A51F-BBE1F82E9C7F

UN-Habitat. (2022). Multi-Level Governance for Effective Urban Climate Action in the Global South. *United Nations Human Settlements Programme*. www.unhabitat.org

UN-Habitat. (2023). *Rescuing SDG 11 for a Resilient Urban Planet: SDG 11 Synthesis Report*. United Nations Human Settlements Programme; United Nations Human Settlements Programme. https://unhabitat.org/sites/default/files/2023/11/sdg_11_synthesis_report_2023.pdf

UN-Habitat. (2024). *Urban content of NDCs: Local climate action explored through in-depth country analyses*.

UNECA. (2018). World Urbanization Prospects 2018 Highlights. *Department of Economic and Social Affairs*.

UNESCO. (2015). Unlocking the Potential of Urban Communities. Case Studies of Twelve Learning Cities. In *National Institute for Lifelong*. https://files.eric.ed.gov/fulltext/ED564060.pdf

United Nations Economic Commission for Africa (UNECA). (2022). SDG Indicators. In *Department of Economic and Social Affairs*. https://unstats.un.org/sdgs/report/2022/goal-11/

United Nations Economic Commission for Africa (UNECA). (2025). Unlocking municipal finance for sustainable urban services and SDG success in Africa. In *UNECA*. https://www.uneca.org/stories/%5Bblog%5D-unlocking-municipal-finance-for-sustainable-urban-services-and-sdg-success-in-africa

Van der Heijden, J. (2019). Studying urban climate governance: Where to begin, what to look for, and how to make a meaningful contribution to scholarship and practice. *Earth System Governance*, *1*, 100005. https://doi.org/10.1016/j.esg.2019.100005

Wagner, P. M., Torney, D., & Ylä-Anttila, T. (2021). Governing a multilevel and cross-sectoral climate policy implementation network. *Environmental Policy and Governance*, *31*(5), 417–431. https://doi.org/10.1002/EET.1942

World Bank. (2015). Ethiopia Urbanization Review: Urbanization Institutions for aMiddle-Income Etiopia. *The World Bank Group*.

World Bank. (2022). *World Development Report 2022: Finance For An Equitable Recovery*. https://doi.org/10.1596/978-1-4648-1730-4

Zhang, Y., Orbie, J., & Delputte, S. (2020). China's climate change policy: Central–local governmental interaction. *Environmental Policy and Governance*, *30*(3), 128–140. https://doi.org/10.1002/EET.1878

Zhu, L., Neal, M., Goodman, L., & Zinn, A. (2024). Assessing Climate Risk in Marginalized Communities. *Urban Institute*, *March*.

Ziervogel, G., Enqvist, J., Metelerkamp, L., & van Breda, J. (2022). Supporting transformative climate adaptation: community-level capacity building and knowledge co-creation in South Africa. *Climate Policy*, *22*(5), 607–622. https://doi.org/10.1080/14693062.2020.1863180

CHAPTER 4

4. INSTITUTIONAL CONSTRAINTS ON EFFECTIVE URBAN CLIMATE GOVERNANCE IN BAHIR DAR CITY, ETHIOPIA

Based on publication:

Melese, M., Anteneh, M., & Bantigegn, S. (2026). Institutional constraints on effective urban climate governance in Bahir Dar City, Ethiopia. *Discover Sustainability*, *7*(325), 1–30. https://doi.org/10.1007/S43621-026-02655-6

Abstract

UCG is critical for addressing the escalating climate risks in rapidly urbanizing cities, particularly in developing counties like Ethiopia. This study examines the institutional constraints hindering effective UCG in Bahir Dar City, Ethiopia, using a mixed-methods approach that integrates quantitative Structural Equation Modeling (SEM), based on a survey of 162 experts, with qualitative insights from KIIs and policy analysis. The SEM analysis identified seven significant institutional barriers, collectively explaining a substantial portion of the variance in Urban Climate Governance Effectiveness (UCGE). The most influential constraints were Human Resources and Institutional Capacity, followed closely by Deficiencies in Policy and Regulatory Frameworks and Weak Political Will and Commitment, along with other significant operational barriers including finance, coordination, and public awareness. Surprisingly, Regional Political Instability was found to be statistically insignificant, though qualitative data highlighted its disruptive potential. The findings underscore the need for capacity-building, localized policy enforcement, stable leadership, sustainable financing, inter-agency coordination, public engagement, and digital infrastructure to enhance climate resilience. This study provides actionable insights for policymakers in Bahir Dar and similar cities facing governance challenges amid rapid urbanization and climate variability.

Keywords: Factor Analysis, Institutional Constraints, SEM, Urban Climate Governance, Bahir Dar.

4.1. Introduction

The 21st century is increasingly shaped by the convergence of rapid urbanization and climate change, pressures most pronounced in the Global South. Projections suggest that by 2050, 70% of the world's population will reside in urban areas, with Africa's urban population expected to double, underscoring the urgent need for effective UCG to build resilience in these rapidly expanding cities (Dodman et al., 2022; Nhamo et al., 2021; Pande et al., 2023).

However, governance structures in many of these cities are ill-equipped to manage this dual challenge. Institutional barriers including weak regulatory frameworks, fragmented policies, poor inter-agency coordination, and financial constraints undermine the effective implementation of climate action (Hölscher et al., 2019; Pasquini, 2020). These governance gaps are particularly pronounced in emerging cities, where rapid, often informal, expansion intersects with environmental degradation to create a complex and under-resourced governance landscape (Castán-Broto & Westman, 2020; Solorio, 2021).

This convergence is particularly evident in Ethiopia, which is experiencing one of the highest rates of urbanization in Africa and is projected to have 42% of its population living in cities by 2050 (Tessema, 2017). While this growth presents economic opportunities, it simultaneously aggravates environmental stress and overburdens local governance structures. These internal pressures are dangerously compounded by severe climate variability, as rising temperatures and shifting rainfall patterns heighten the risks of both flooding and drought, creating a complex national challenge (Getachew & Manjunatha, 2021).

Bahir Dar City, the capital of the ANRS, exemplifies these intertwined challenges. Since 1994, the city's rapid expansion has driven major land use changes, including the spread of informal settlements and encroachment on the ecological buffer of Lake Tana (Dadi, 2018; Kindu et al., 2020; Wubie et al., 2020). These dynamics resonate with patterns seen in other rapidly urbanizing African cities struggling with unplanned growth and environmental stress (Rivas et al., 2023). Consequently, Bahir Dar faces intensified climate-related hazards such as increased flooding, rising urban heat, and green space depletion, making effective UCG a critical and urgent necessity (Balew & Korme, 2020; Debebe & Miteku, 2023; Getu & Bhat, 2024).

Despite this pressing urgency, significant research gaps persist. First, there is a critical empirical gap concerning the on-the-ground institutional effectiveness of UCG in Ethiopia's rapidly expanding secondary cities. Existing scholarship in Ethiopia predominantly focuses on national-level policies or the unique challenges of the capital, Addis Ababa (Addis et al., 2022;

Gedefaw et al., 2019), thereby overlooking the distinct institutional dynamics and implementation capacities at the municipal level in cities like Bahir Dar.

Second, this empirical oversight contributes to a theoretical gap. While frameworks like Adaptive Governance provide a normative ideal for resilience, and Institutional Capacity Theory offers a diagnostic lens, there is a lack of research that empirically connects the two. Specifically, a gap exists in understanding how specific, measurable deficits in foundational institutional capacity (e.g., in human resources, finance, or policy enforcement) directly inhibit the development of the core attributes of adaptive governance such as social learning, flexibility, and polycentric coordination particularly within the context of a rapidly urbanizing secondary city. This limited understanding of the interplay between foundational capacities and adaptive outcomes hinders the development of targeted governance strategies vital for building climate resilience in similar rapidly growing urban centers across the Global South.

Thus, this study aims to fill this gap through a mixed-methods investigation of the institutional constraints limiting Bahir Dar's capacity to implement effective climate action. Specifically, this study addresses three central questions. First, what are the key institutional constraints hindering effective UCG in Bahir Dar? Second, what is their relative influence on overall governance effectiveness? Third, how do these barriers manifest in practice according to diverse local stakeholders? By answering these questions, the study contributes a robust, evidence-based understanding of governance challenges in a rapidly urbanizing city. The findings are intended to inform targeted policy interventions and support the development of more resilient and adaptive governance frameworks in Bahir Dar and similar contexts.

4.1.1. Theoretical Framework (Institutional Capacity as a Precondition for Adaptive Governance)

To systematically analyze the multifaceted barriers to effective UCG, this study employs an integrated theoretical approach. The analysis is situated within the broader goal of achieving Adaptive Governance, a framework highly relevant to managing the uncertainty and complexity of climate change in social-ecological systems. Adaptive governance emphasizes flexibility, social learning, and polycentric networks as essential for building resilience (Folke, Hahn, & Norberg, 2005). However, a governance system cannot become adaptive without a foundational set of resources and capabilities. Therefore, Institutional Capacity Theory is used as the primary diagnostic lens for this research.

Institutional Capacity Theory posits that the effectiveness of governance is fundamentally determined by the collective abilities, resources, and structural arrangements of its institutions to perform functions, solve complex problems, and achieve objectives (World Bank, 2011). In this study, strong institutional capacity is conceptualized as a necessary precondition for the emergence of adaptive governance. The concept of institutional capacity is operationalized through several critical dimensions, which directly inform the analysis of the constraints preventing adaptive governance in Bahir Dar.

The first of these is Human and Technical Capacity, which refers to the availability of skilled personnel, technical expertise, and the relevant data and technology required to design, implement, and monitor climate policies. A deficit in this area can lead to poorly designed interventions and a lack of evidence-based decision-making (UNDP, 2011). A second critical dimension is Financial Capacity, which involves the ability to mobilize, allocate, and manage sufficient and sustainable financial resources for climate action. This includes not only the availability of funds but also the institutional mechanisms for budgeting and financial planning (World Bank, 2011).

Furthermore, Structural and Regulatory Capacity pertains to the existence of clear policies, robust legal and regulatory frameworks, and well-defined institutional mandates and roles. A weakness here often manifests as a "policy-implementation gap" where formal rules lack functional enforcement (Domorenok et al., 2021). This is closely linked to Political Capacity, the dimension that centers on the political will, leadership commitment, and stability required to prioritize climate change on the policy agenda and sustain action over time. Political capacity is often the driving force that activates or deactivates other capacities (UNDP, 2011). Finally, Relational Capacity involves the ability of institutions to coordinate and collaborate effectively across different government agencies and with external stakeholders, including civil society and the private sector. Fragmented or "siloed" governance structures indicate a weakness in this dimension (World Bank, 2023).

By employing Institutional Capacity Theory as the primary analytical lens, this study moves beyond a simple description of barriers. It provides a structured framework to systematically disaggregate, measure, and understand how weaknesses across these interconnected dimensions collectively undermine the overall effectiveness of UCG. In essence, this research diagnoses the specific institutional capacity deficits that inhibit the potential for adaptive governance in Bahir Dar. The following research hypotheses are directly derived from this

theoretical understanding, postulating that deficiencies in each of these core capacity dimensions are negatively associated with governance effectiveness.

4.1.2. Research Hypotheses

In line with the theoretical framework, this study tests the relationships between eight key institutional constraints and UCGE. For each constraint, a null hypothesis (H_0) and a corresponding alternative hypothesis (H_1-H_8) were formulated. The overarching null hypothesis for all tests is that there is no statistically significant relationship between the institutional constraint and UCGE.

The study seeks to find evidence to reject the null hypotheses in favor of the following eight alternative hypotheses.

H_1: Deficiencies in Policies and Regulatory Frameworks are negatively associated with UCGE.

H_2: Inadequacies in Financing and Budget Allocation are negatively associated with UCGE.

H_3: A lack of Human Resources and Institutional Capacity is negatively associated with UCGE.

H_4: Deficits in Technology and Data Management are negatively associated with UCGE.

H_5: A weak Political Will and Commitment is negatively associated with UCGE.

H_6: Insufficient Information and Public Awareness is negatively associated with UCGE.

H_7: Poor Institutional Coordination and Collaboration is negatively associated with UCGE.

H_8: The presence of Regional Political Instability is negatively associated with UCGE.

4.2. Methods and Materials

4.2.1. Study area description

A. Geographic, Environmental and Socio-Economic Context

Bahir Dar, the capital of Amhara National Regional State (ANRS), is a fast-growing urban center located along the southern shores of Lake Tana. Geographically, it spans from 11°25'11" to 11°58'11"N latitude and 37°2'2" to 37°42'4"E longitude, covering ≈235 km² (**Error! eference source not found.**). The city is situated about 567 km northwest of Addis Ababa (Asmamaw & Debie, 2023). Elevations range from 1,708 to 2,007 meters, with predominantly gentle slopes (3-10%) and some steeper gradients (>20%) shaped by the Abay River, which contributes to the area's vulnerability to flooding.

Bahir Dar exhibits a tropical savannah (*Woina Dega*) climate. The average annual temperature ranges from 17°C to 22°C, with highs peaking in April and May at around 28.5°C, and lows dipping to 8.6°C in December. Rain falls between March and September, peaking in July and

August with over 400 mm monthly. The dry season, from October to February, receives minimal precipitation.

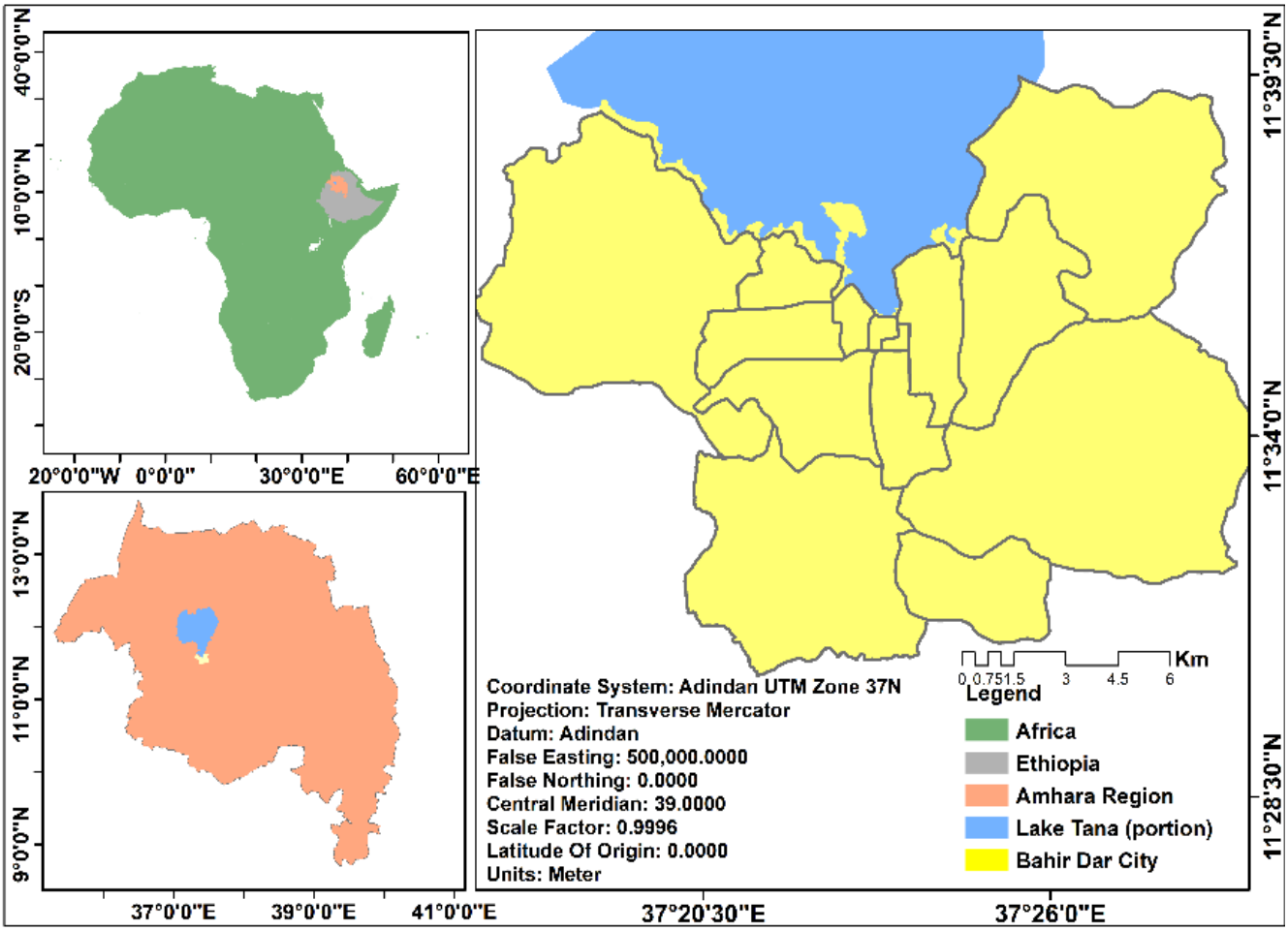


Figure 4.0.1 Study area map

Bahir Dar's trajectory from a historical center to a modern urban hub frames its current governance challenges. While its origins date to the 14th century, its transformation accelerated after it became the regional capital in 1994 (Appelhans, 2017; Seyoum, 2014). This status catalyzed dramatic population growth, with the city swelling from ≈55,000 in 1984 to an estimated 500,000 by 2020, driven by migration and a diverse economy based on agriculture, services, and tourism centered on Lake Tana and the Blue Nile Falls (Bahir Dar City Structural Plan Preparation Project Office, 2020; CSA, 1984; UNESCO, 2015). This explosive demographic and economic growth has fuelled rapid urban sprawl, placing immense pressure on infrastructure and local governance systems and underscoring the urgency of building climate resilience.

B. Institutional and Governance Context

Ethiopia is a federal state, and Bahir Dar's governance structure operates within this multi-level system, subordinate to both federal and ANRS regulations. The Bahir Dar City Administration

serves as the primary municipal authority, responsible for overall urban management and the implementation of development plans. However, responsibility for climate-relevant sectors is distributed across several key government organs, creating a complex institutional landscape. Key actors in the city's UCG include

1. The City Land Development and Management Office, which holds primary responsibility for urban planning, land use zoning, and regulating construction which are activities central to managing urban expansion and the related risk.
2. The City Environmental Protection Office, which is mandated to enforce environmental regulations, manage green spaces, and oversee waste management. However, its mandate for climate-specific action is often less clearly defined and resourced.
3. Other sectoral bureaus, such as those for Water and Sewerage Services, Roads and Transport, and Health, whose operations have direct implications for the city's climate resilience (e.g., drainage infrastructure, public transport, and public health responses to climate impacts).

This fragmented distribution of responsibilities means that effective climate governance in Bahir Dar is highly dependent on the capacity for coordination and collaboration among these various municipal bodies, as well as with regional (ANRS) and federal agencies. The competencies of these city-level organs are often constrained by budget allocations from the regional government and by national-level policy directives, creating a challenging context for developing and implementing localized, integrated climate action. This study, therefore, investigates the institutional constraints operating within this specific multi-actor and multi-level governance arrangement.

4.2.2. Research Approach and Design

This study adopted a convergent mixed-methods design with sequential analysis to examine institutional constraints on UCG (Creswell, 2009; Tashakkori & Teddlie, 2003). Quantitative survey data and qualitative insights from KIIs and field observations were collected concurrently. However, the analysis followed a sequential logic i.e. quantitative data were first analyzed to identify predictors of governance effectiveness, after which qualitative data were thematically examined to explain and contextualize these statistical results. Both strands were integrated in the discussion to provide a comprehensive interpretation of institutional barriers.

4.2.2.1. Population and Sampling Procedure

This study was conducted in Bahir Dar City, a purposively selected case study due to its rapid urban expansion and acute climate-related challenges (Adigeh & Abebe, 2023; Digafe et al.,

2024; Getu & Gangadhara Bhat, 2024). A mixed-methods sampling approach was used, with distinct strategies for the quantitative and qualitative components.

A. Quantitative Survey: Population and Sample

The quantitative component of this study targeted a purposively defined population of professionals with direct involvement in climate-relevant governance in Bahir Dar. This population was defined as all technical and managerial staff whose roles relate to urban planning, environmental management, infrastructure, and policy implementation. This group explicitly includes technical experts (e.g., planners, environmental experts) as well as team leaders and managers/leaders within the relevant government offices at the regional, city, and sub-city levels.

The study conducted a census of this defined population, targeting all identified and available individuals. The final sample comprised 162 professionals from the regional (n=17), city (n=37), and sub-city (n=108) administrative levels. This census approach was chosen over sampling to capture the complete spectrum of professional perspectives within the formal governance structure. The focus on this expert population was intentional; the survey was designed as a tool to assess specific, often technical, institutional and operational constraints, which requires a deep and informed understanding of the internal workings of the governance system.

B. Qualitative Interviews and Sample Selection

For the qualitative component, a purposive sampling strategy was used to select 16 KIs who could provide diverse and in-depth perspectives. Recognizing that a full understanding of governance requires more than expert assessment, this sample was intentionally stratified to include the voices of those outside the formal government structure. The sample included six government officials, four community members, three private sector representatives, and three leaders from CSOs. Selection was based on the participants' roles and direct experience with UCG challenges.

C. Rationale for Mixed-Methods Sampling

This mixed-methods sampling strategy allowed for a robust triangulation of data. The focus on an expert population for the quantitative survey was intentional, as the survey was designed as a diagnostic tool to assess specific, often technical, institutional constraints. While this approach provides deep internal insights, we acknowledge its limitations concerning broader representativeness. Therefore, the qualitative sample was explicitly designed to include diverse stakeholder groups (including citizens) to provide the rich, multi-stakeholder context necessary

to understand how these constraints manifest and are experienced by the wider community. This triangulation mitigates the potential for bias stemming from any single perspective.

4.2.2.2. Data Sources and Collection procedure

This study utilized both primary and secondary data sources to gather comprehensive quantitative and qualitative information.

A. Quantitative data (Survey Instrument and Procedure)

To gather quantitative data, a structured questionnaire was developed. The survey was designed to measure experts' perceptions regarding the severity of various institutional constraints on a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

The development of the survey instrument followed a rigorous multi-stage process to ensure validity and reliability. First, an initial pool of items for each institutional constraint was derived from a comprehensive review of established governance literature and existing climate governance assessment tools. Second, these generic items were carefully adapted to reflect the specific political, economic, and social context of Bahir Dar, informed by preliminary document analysis and informal discussions with local academics. Third, the draft instrument was validated for content, clarity, and relevance by a panel of five academic and five practitioner experts not included in the final sample. Based on their feedback, several items were rephrased or removed. Finally, a pilot test was conducted with a small group of 10 experts to refine the wording, format, and overall flow of the questionnaire before full administration. The survey instrument was structured around nine key concepts, which were conceptualized as latent constructs for the purpose of analysis. These included eight independent variables representing the institutional constraints and one dependent variable representing UCGE. A description of each construct is provided below.

i. **Independent Latent Variables (Institutional Constraints)**

Policies and Regulatory Frameworks (PRF): This construct examined the presence and enforcement of climate-related policies, the clarity of institutional mandates, and the degree of legal compliance in climate governance.

Financing and Budget Allocation (FBA): This factor assessed the availability and efficiency of financial resources for climate action. It included indicators such as funding reliability, budget allocation, financial incentives for climate initiatives, and reliance on external donor support.

Human Resources and Institutional Capacity (HIC): This dimension analyzed the availability of trained personnel, staff retention rates, capacity-building programs, and technical expertise for implementing climate policies.

Technology and Data Management (TDM): This construct evaluated the availability of climate monitoring tools, access to digital platforms, early warning systems, and institutional capacity to utilize climate data for decision-making.

Political Will and Commitment (PWC): This factor measured the level of commitment among political leaders to implement climate policies. It included indicators such as leadership stability, prioritization of climate governance in policy agendas, and accountability in climate-related decision-making.

Information and Public Awareness (IPA): This dimension assessed transparency in climate governance, the availability of climate-related information for stakeholders, and public engagement in climate initiatives.

Institutional Coordination and Collaboration (ICC): This factor focused on the degree of collaboration between government agencies, the private sector, and civil society organizations in climate governance.

Regional Political Instability (RPI): This construct examined the impact of political instability on climate governance. Indicators included disruptions in governance structures, resource allocation challenges due to conflict, and reduced international support for climate initiatives.

ii. **Dependent Latent Variable (UCGE)**

The dependent variable, UCGE, was also conceptualized as a latent construct. This approach conceptualizes governance effectiveness not as a single metric, but as a multifaceted outcome reflecting the successful implementation of key governance principles. The UCGE construct was measured using seven observed variables derived from the survey including accountability (ACCON), public participation (PARTP), equity (EQUITY), awareness-raising (AWARN), institutional strength (INSTIT), adaptability (ADAPT), and the enforcement of climate change laws (CCLAW).

Table 4.1 Definition of Latent Constructs and their Corresponding Indicator Items

Latent Construct	Indicator Code	Indicator Item Description
PRF	PR1	Absence of comprehensive climate policies at the local level
	PR2	Weak enforcement and compliance mechanisms for existing regulations
	PR3	Lack of policy integration between national, regional, and local levels
	PR4	Absence of climate adaptation and mitigation strategies tailored to local contexts
	PR5	Inadequate monitoring and evaluation frameworks for climate governance implementation
	PR6	Limited public participation in climate-related decision-making processes
	PR7	Ambiguity in institutional roles and responsibilities in climate governance
	PR8	Local government authority constraints over key climate-related policies
FBA	FB1	Lack of dedicated and sustainable funding sources for climate governance
	FB2	Insufficient financial resources for implementing climate adaptation and mitigation plans
	FB3	Inefficient allocation and utilization of climate-related budgets
	FB4	Dependency on external donors for climate action financing
	FB5	Limited financial incentives for private sector engagement in climate governance
HIC	HI1	Shortage of trained personnel in urban climate governance
	HI2	High turnover of skilled professionals in environmental governance offices
	HI3	Limited professional development and capacity-building programs for climate governance personnel
	HI4	Inadequate technical expertise to design and implement climate strategies
TDM	TD1	Limited access to modern climate adaptation technologies
	TD2	Absence of digital platforms for climate data collection and monitoring
	TD3	Weak data-sharing mechanisms between government institutions
	TD4	Lack of early warning systems for climate-related disasters
	TD5	Inadequate research and development support for climate innovations
PWC	PC1	Lack of strong political commitment to climate action at local levels
	PC2	Frequent changes in government leadership affecting policy continuity
	PC3	Limited prioritization of climate governance in urban development plans
	PC4	Weak accountability mechanisms for climate policy implementation
IPA	IP1	Limited awareness and engagement of communities in climate governance
	IP2	Lack of transparency in climate governance decisions and actions
	IP3	Limited availability of localized climate data for decision-making
	IP4	Inadequate climate education and awareness programs for the public
ICC	IC1	Weak coordination between different government agencies involved in climate governance
	IC2	Limited engagement of private sector and civil society in climate governance
	IC3	Absence of multi-stakeholder platforms for climate governance discussions
	IC4	Fragmented institutional mandates leading to overlapping responsibilities
RPI	RP1	Impact of regional conflicts on climate governance initiatives
	RP2	Political instability affecting resource allocation for climate programs
	RP3	Disruptions in governance structures due to regional crises
	RP4	Limited international cooperation and support due to instability
UCGE	ACCON	Accountability
	PARTP	Public participation
	EQUITY	Equity
	AWARN	Awareness-raising
	INSTIT	Institutional strength
	ADAPT	Adaptability
	CCLAW	Climate Change Law and Enforcement

These indicators were selected based on established frameworks of good governance and climate resilience, providing a comprehensive measure of the perceived performance of the urban governance system. The specific observed indicators (survey items) used to measure each of these nine latent constructs are detailed in Table 4.1.

Following the finalization of the instrument, data was collected through face-to-face administration by a team of trained enumerators. Of the 162 experts targeted in the census, all 162 participated, resulting in a 100% response rate.

B. Qualitative and Secondary Data Collection and Procedure

To complement and explain the quantitative findings, primary qualitative data were collected through two methods. First, semi-structured KIIs were conducted with 16 key stakeholders (11 male, 5 female). This group was comprised of six government officials (including senior planners and bureau heads), four community members (including community elders), three private sector representatives (including owners of construction firms and tourism businesses), and three leaders from CSOs active in environmental advocacy. Second, Field Observations were conducted to document on-the-ground evidence of climate impacts and governance responses, focusing on drainage infrastructure, green space management, and land use patterns. Additionally, Secondary Data were gathered through Document Analysis of official reports, including Ethiopia's National Adaptation Plan (NAP-ETH), municipal urban planning frameworks, government reports, and budget records, to provide data on existing policies and governance structures.

4.2.3. Methods of Data Analysis

4.2.3.1. Quantitative Data Analysis

The quantitative data were analyzed to measure the latent constructs and test the hypothesized relationships. A simple data aggregation method, such as calculating an average score for the items within each construct, was not used. Instead, a more robust latent variable modeling approach was employed. This approach uses the covariance structure of the observed indicator items to estimate the underlying unobserved (latent) construct, a process that explicitly accounts for measurement error and provides a more valid and reliable assessment than simple averaging. This was conducted through a three-step process: Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and finally, Structural Equation Modeling (SEM), using IBM SPSS Statistics (Version 20) and IBM SPSS AMOS (Version 26).

A. Exploratory Factor Analysis

EFA was first performed to identify the underlying factor structure of the 38 survey items. The suitability of the data for factor analysis was confirmed through the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which exceeded the recommended threshold of 0.60, and Bartlett's Test of Sphericity, which was statistically significant ($p < .001$). Principal Component Analysis with Varimax rotation was used for factor extraction. Factors with eigenvalues greater than 1.0 were retained, and items with factor loadings below 0.50 were considered for removal.

B. Confirmatory Factor Analysis

Following the EFA, a CFA was conducted to test the validity and reliability of the proposed measurement model. Model fit was assessed using multiple standard indices like the Normed Chi-square (χ^2/df), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA). To establish the psychometric properties of the model, we assessed construct reliability using Composite Reliability (CR), convergent validity using Average Variance Extracted (AVE), and discriminant validity using the Fornell-Larcker criterion.

C. Structural Equation Modeling

Once the measurement model was validated through CFA, SEM was used to examine the relationships between the eight identified latent constructs and their impact on UCGE. SEM was chosen because it allows for testing complex relationships between multiple independent and dependent variables simultaneously. The model was specified by equation (16.

$$UCGE = \beta_1 PRF + \beta_2 FBA + \beta_3 HIC + \beta_4 TDM + \beta_5 PWC + \beta_6 IPA + \beta_7 ICC + \beta_8 RPI + \varepsilon \quad (16)$$

Where UCGE = Urban Climate Governance effectiveness,

PRF = Policies and Regulatory Frameworks,

FBA = Financing and Budget Allocation,

HIC = Human Resources and Institutional Capacity,

TDM = Technology and Data Management,

PWC = Political Will and Commitment,

IPA= Information and Public Awareness,

ICC = Institutional Coordination and Collaboration,

RPI = Regional Political Instability,

β1 to β8 = Regression coefficients representing the strength of the relationships and

ε = Error term.

The standardized path coefficients (β-values) and their significance levels (p-values) were used to determine the outcome of the hypothesis tests.

4.2.3.2. Qualitative Data Analysis

Qualitative data from the 16 KIIs, field observation notes, and document reviews were analyzed using thematic analysis, following the systematic approach outlined by Braun & Clarke (2006). This involved an iterative process of data familiarization, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Recurring themes focused on governance constraints, stakeholder engagement, and policy enforcement, which were used to explain and contextualize the quantitative findings.

4.2.3.3. Data Integration and Triangulation

In line with our convergent parallel mixed-methods design, the findings from the quantitative (SEM) and qualitative (thematic) analyses were triangulated during the interpretation phase. Statistical results from SEM were compared with qualitative themes, field observations, and policy reviews to develop a comprehensive and well-rounded discussion of the institutional barriers affecting UCGE in Bahir Dar.

4.3. Result

4.3.1. Exploratory Factor Analysis

4.3.1.1. Data Suitability and Preliminary Analysis

The initial phase of data analysis involved an EFA to identify the underlying latent structure of institutional constraints affecting UCGE in Bahir Dar. Prior to factor extraction, the dataset's suitability for EFA was assessed. The KMO measure of sampling adequacy yielded a value of 0.896, which is considered "meritorious" and well above the recommended threshold of 0.60 (Table 4.2). This indicates a high degree of common variance among the items, making the dataset highly suitable for factor analysis. Furthermore, Bartlett's Test of Sphericity was highly significant (χ^2 (703) = 5807.115, $p < .001$). This result rejects the null hypothesis that the correlation matrix is an identity matrix, confirming the presence of patterned, factorable relationships among the variables.

Table 4.2 Kaiser-Meyer-Olkin Measure and Bartlett's Test results

KMO Measure of Sampling Adequacy		.896
Bartlett's Test of Sphericity	Approx. Chi-Square	5807.115
	df	703
	Sig.	.000

4.3.1.2. Factor Extraction and Communalities

PCA was employed as the extraction method, with factor retention based on the Kaiser criterion (eigenvalues >1). Eight factors were extracted, explaining 68.77% of the total variance (Table 4.3). Since a cumulative variance above 60% is generally acceptable in social sciences (Hair, 2011), this indicates a robust factor solution that captures the main institutional constraints.

The communalities (h^2), which represent the proportion of variance in each item explained by the eight-factor solution, were also examined. Most items exhibited strong communalities ($h^2 > 0.60$), confirming they were well-represented. For instance, items such as *'frequent changes in political leadership'* (PC2, $h^2 = .869$), *'inadequate climate education programs'* (IP4, $h^2 = .838$), and *'absence of tailored climate adaptation strategies'* (PR4, $h^2 = .832$) were highly explained by the solution (Table 4.3).

Conversely, a few items displayed low communalities and were subsequently removed from the model. These included 'ambiguity in institutional roles' (PR7, $h^2 = .179$), and two items related to political instability; 'limited international cooperation and support due to instability' (RP4, $h^2 = .208$) and 'disruptions in governance structures due to regional crises' (RP3, $h^2 = .063$). The poor performance of these items suggests they represent concepts that the experts perceive as distinct from the eight core factors that emerged.

The low communalities of the two instability items (RP3 and RP4) suggests that the experts conceptually separated the chronic, internal dysfunctions of the governance system from the acute, external shocks of regional instability. Because these items did not describe the day-to-day workings of the institutions, they failed to load cleanly onto the primary factors.

The low communality of 'ambiguity in institutional roles' (PR7) failure to load onto any single factor suggests it is not perceived as a discrete problem. Instead, it is likely seen as a cross-cutting, systemic dysfunction that is a symptom of multiple other constraints including weak policies, fragmented coordination, and high staff turnover. Because this ambiguity permeates nearly all aspects of the governance system, it lacks a unique statistical identity, a finding which itself underscores the deeply entrenched nature of the institutional challenges in Bahir Dar.

4.3.1.3. Factor Rotation, Interpretation, and Naming

To enhance interpretability, a Varimax rotation with Kaiser Normalization was applied. The rotated component matrix (Table 4.3) revealed a clear and simple structure, with most items

loading strongly on a single factor, allowing for meaningful interpretation and naming.

Table 4.3 Rotated Component Matrix of Institutional Constraints to UCG

	Component							
	1	2	3	4	5	6	7	8
PR1	.813							
PR2	.798							
PR3	.829							
PR4	.849							
PR5	.885							
PR6	.810							
PR7								
PR8	.725							
FB1		.739						
FB2		.858						
FB3		.832						
FB4		.832						
FB5		.778						
HI1							.836	
HI2							.785	
HI3							.805	
HI4							.794	
TD1			.675					
TD2			.817					
TD3			.862					
TD4			.756					
TD5			.780					
PC1				.886				
PC2				.919				
PC3				.871				
PC4				.899				
IP1					.866			
IP2					.853			
IP3					.886			
IP4					.901			
IC1						.848		
IC2						.781		
IC3						.872		
IC4						.823		
RP1								.745
RP2								.843
RP3								
RP4								
% of Variance	**13.39**	**9.87**	**9.17**	**8.81**	**8.48**	**7.83**	**7.03**	**4.18** **Total=68.77**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

The eight extracted factors represent distinct dimensions of institutional constraints. The factors were named based on the thematic clustering of their highest-loading items; (1) Policies and Regulatory Frameworks, defined by items related to inadequate policy monitoring and

enforcement; (2) Financing and Budget Allocation, capturing insufficient and externally dependent funding; (3) Technology and Data Management, reflecting weak data-sharing and digital platforms; (4) Political Will and Commitment, characterized by leadership turnover and weak accountability; (5) Information and Public Awareness, concerning poor public education and engagement; (6) Institutional Coordination and Collaboration, representing fragmented mandates and a lack of multi-stakeholder platforms; (7) Human Resources and Institutional Capacity, highlighting a shortage of trained personnel; and (8) Regional Political Instability, related to conflict-driven disruptions.

Generally, the EFA successfully reduced the 38 survey items into eight distinct, reliable, and interpretable factors. These factors represent the core institutional constraints to effective UCG in Bahir Dar and provide a validated structure for the subsequent CFA and SEM. Based on the EFA results, three indicators (PR7, RP3, and RP4) demonstrated poor performance, with communalities and factor loadings below the accepted threshold (< 0.40). Consequently, these items were removed from the model before proceeding to CFA, as they did not meaningfully contribute to any latent construct.

4.3.2. Confirmatory Factor Analysis (The Measurement Model)

Following the successful identification of the eight-factor structure through EFA, a CFA was conducted to validate this measurement model. The purpose of the CFA was twofold; first, to assess how well the proposed eight-factor model fits the observed data, and second, to establish the reliability and validity of the latent constructs. This validated measurement model is a prerequisite for testing the structural relationships in the subsequent SEM.

4.3.2.1. Assessment of Model Fit

The overall fit of the eight-factor measurement model was evaluated using several standard goodness-of-fit indices, as recommended in contemporary SEM literature. The results of this assessment are summarized in Table 4.4.

As is common with large sample sizes, the Chi-square (χ^2) test was statistically significant. However, greater emphasis was placed on the other indices. As shown in Table 4.4, the model demonstrated an excellent fit across all other key metrics. The normed Chi-square (χ^2/df) was 1.77, falling well within the acceptable range. The incremental fit indices, CFI (.911) and TLI (.900), both exceeded the recommended threshold of .90. Furthermore, the absolute fit index, RMSEA, was .062, a value indicating a good model fit.

Table 4.4 Goodness-of-Fit Indices for the CFA Measurement Model

Fit Index	Mnemonic	Recommended Value	Model Value	Interpretation
Chi-square	χ^2 (df)	p > .05	943.390 (532)	Significant (p<.001)
Normed Chi-square	χ^2/df	< 3.0	1.77	Good Fit
Comparative Fit Index	CFI	≥ .90	.911	Good Fit
Tucker-Lewis Index	TLI	≥ .90	.900	Good Fit
Root Mean Square Error of Approximation	RMSEA	≤ .08	.062	Good Fit

Collectively, these indices provide strong and consistent evidence that the eight-factor measurement model, derived from the EFA, provides a robust and acceptable fit to the observed data. The validated measurement model, showing all standardized estimates and inter-construct correlations, is presented in Figure 4.0.2.

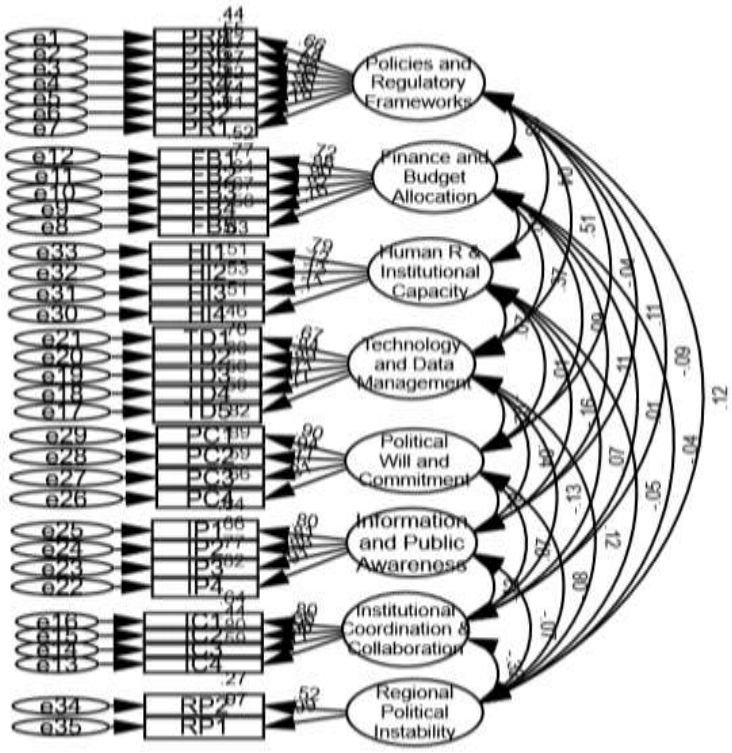


Figure 4.0.2 The CFA Measurement Model with Standardized Estimates

4.3.2.2. Measurement Model Reliability and Validity

With model fit established, the next step was to assess the reliability and validity of the latent constructs.

i. **Construct Reliability**

The internal consistency of the constructs was evaluated using Composite Reliability (CR). As shown in Table 4.5, the CR values for all eight factors ranged from .751 to .934. Since all values

are well above the recommended threshold of .70, this confirms that the measurement items for each construct are consistently and reliably measuring the same underlying latent variable.

ii. Convergent Validity

Convergent validity, the degree to which items intended to measure a construct are in agreement, was assessed using the following two criteria.

1. **Standardized Factor Loadings (λ):** All factor loadings were statistically significant ($p < .001$) and substantial in magnitude, ranging from .523 to .986. The majority of loadings were well above .70, indicating that the observed variables are strongly related to their posited latent constructs.
2. **Average Variance Extracted (AVE):** The AVE values, which represent the proportion of variance in the indicators explained by the latent construct, ranged from .545 to .741 (Table 4.5). As all values exceeded the recommended minimum of .50, this confirms that each construct explains more than half of the variance in its respective indicators, providing strong support for convergent validity.

iii. Discriminant Validity

Discriminant validity ensures that the latent constructs are distinct from one another. This was assessed using the Fornell-Larcker criterion, which requires that the square root of the AVE for each construct must be greater than its correlation with any other construct. As presented in Table 4.5, the diagonal elements (**in bold**) represent the square root of the AVE for each construct. In every case, this value is greater than the off-diagonal inter-construct correlation coefficients in its corresponding row and column (Table 4.5). For example, the square root of AVE for 'Policies and Regulatory Frameworks' is .819, which is greater than its correlation with any other factor (e.g., .379 with 'Financing', .514 with 'Technology'). This pattern holds for all eight factors, providing clear evidence of discriminant validity.

Generally, the CFA has successfully validated the eight-factor structure of institutional constraints to UCG. The measurement model demonstrated a good fit to the data and met the stringent requirements for construct reliability, as well as convergent and discriminant validity. This rigorous validation confirms that the eight latent constructs are sound, reliable, and distinct. With a validated measurement model in place, the analysis can now proceed to the final stage of SEM, to test the hypothesized relationships between these institutional constraints and the overall effectiveness of UCG.

Table 4.5 Assessment of Construct Reliability and Validity

	CR	AVE	MSV	MaxR(H)	RPI	PRF	FBA	ICC	TDM	IPA	PWC	HIC
RPI	0.751	0.623	0.104	0.972	**0.789**							
PRF	0.934	0.670	0.264	0.951	0.118	**0.819**						
FBA	0.896	0.634	0.144	0.905	-0.036	0.379	**0.796**					
ICC	0.865	0.618	0.104	0.890	-0.323	-0.086	0.007	**0.786**				
TDM	0.885	0.608	0.264	0.90	0.116	0.514	0.372	-0.126	**0.780**			
IPA	0.912	0.722	0.032	0.921	-0.073	0.112	0.110	0.131	-0.040	**0.849**		
PEC	0.919	0.741	0.032	0.942	-0.082	-0.036	0.086	0.070	-0.015	0.178	**0.861**	
HIC	0.827	0.545	0.025	0.831	-0.054	0.040	-0.006	0.069	0.067	-0.158	0.013	**0.738**

Notes: Diagonal elements (bold) are the square root of the AVE. Off-diagonal elements are the inter-construct correlations. For discriminant validity, diagonal values must be greater than the values in their respective row and column. CR = Composite Reliability; AVE = Average Variance Extracted; MSV = Maximum Shared Variance; MaxR(H) = Maximum Reliability.

4.3.3. Structural Equation Modeling (Testing the Structural Relationships)

Following the validation of the measurement model via CFA, the full structural model was tested to examine the hypothesized relationships between the eight institutional constraints and the core outcome variable UCGE. This final stage of the analysis allows for the simultaneous testing of all hypotheses and the determination of the relative influence of each constraint.

4.3.3.1. Structural Model Fit

Before assessing the individual paths, the overall fit of the structural model was evaluated. As shown in Table 4.6, the model demonstrated an acceptable fit to the data, confirming its structural integrity. The normed Chi-square (χ^2/df) was (1276.656 / 783) 1.630, falling well within the recommended range of 1 to 3. The CFI was .916, exceeding the threshold of .90. The TLI, at .886, was slightly below the conventional .90 cutoff, but is often considered acceptable for complex models. Crucially, the RMSEA was .056, a value that indicates a good model fit, with a 90% confidence interval of .050 to .061. Collectively, these indices confirm that the structural model provides a solid foundation for interpreting the hypothesized path relationships.

Table 4.6 Goodness-of-Fit Indices for the Structural Model

Fit Index	Mnemonic	Recommended Value	Model Value	Interpretation
Chi-square/df	χ^2/df	< 3.0	1.630	Good Fit
Comparative Fit Index	CFI	≥ .90	.916	Good Fit
Tucker-Lewis Index	TLI	≥ .90	.886	Acceptable Fit
Root Mean Square Error of Approximation	RMSEA	≤ .08	.056	Good Fit

4.3.3.2. Explanatory Power of the Model

The explanatory power of the model was assessed by examining the squared multiple correlation (R^2) for the endogenous variable, UCGE. The results revealed an R^2 value of .65 (Figure 4.0.3), indicating that the eight institutional constraints collectively explain 65% of the variance in the perceived effectiveness of UCG in Bahir Dar. This suggests a robust model in capturing the influence of these institutional factors.

4.3.3.3. Hypothesis Testing

The core of the SEM analysis involved testing the eight hypothesized paths leading from each institutional constraint to UCGE. The standardized path coefficients (β), critical ratios (C.R.), and p-values for each hypothesis are presented in Table 4.7.

Table 4.7 Results of Hypothesis Testing for the Structural Model

Hypothesized Path	Standardized Estimate (β)	C.R.	P-value	Outcome
H1: Policies & Reg. Frameworks → UCGE	-.285	3.154	.002	Supported
H2: Financing & Budget → UCGE	-.241	2.971	.003	Supported
H3: Human Resources & Capacity → UCGE	-.312	3.784	.001	Supported
H4: Technology & Data Mgmt. → UCGE	-.198	2.427	.015	Supported
H5: Political Will & Commitment → UCGE	-.276	3.033	.002	Supported
H6: Information & Public Awareness → UCGE	-.209	2.504	.012	Supported
H7: Institutional Coordination → UCGE	-.223	2.899	.004	Supported
H8: Regional Political Instability → UCGE	-.421	1.538	.124	Not Supported

*Notes: Significance set at p < .05. UCGE = Urban Climate Governance Effectiveness.
Model R^2 for UCGE = .65*

The structural model was used to test the eight hypotheses, revealing a clear hierarchy of institutional constraints that influence the effectiveness of UCG in Bahir Dar. The analysis provided robust statistical support for seven of the eight hypotheses, with the findings detailed below and summarized in Table 4.7.

Hypothesis 3: Human Resources and Institutional Capacity (HIC) emerged as the most powerful and significant predictor of UCGE (β = -.312, p < .001). This is the strongest path in the model, indicating that the availability of trained staff, adequate technical expertise, and measures to ensure staff retention are the most critical factors driving the success of climate governance in Bahir Dar. Deficiencies in this area represent the single greatest constraint.

Hypothesis 1: Policies and Regulatory Frameworks (PRF) was the second most influential factor (β = -.285, p = .002). This result provides strong evidence that the existence of clear,

integrated, and well-enforced climate policies and regulations is a fundamental prerequisite for effective governance. A weak policy environment is a major barrier to progress.

Hypothesis 5: Political Will & Commitment demonstrated a strong, significant impact on UCGE (β =- .276, p = .002). This finding underscores the crucial role of stable political leadership and the consistent prioritization of climate change on the urban agenda. Without sustained political backing, governance efforts are significantly hampered.

Hypothesis 2: Financing & Budget Allocation also proved to be a significant barrier (β = -.241, p = .003). This goes beyond a simple lack of funds to encompass issues of reliability and efficiency. The finding suggests that dedicated and sustainable funding sources for climate action are insufficient, that the allocation and utilization of existing climate-related budgets are inefficient, and that a dependency on external donors may hinder the development of self-sustaining local financial strategies.

Hypothesis 7: Institutional Coordination & Collaboration factor's significance (β = -.223, p = .004) points to critical failures in inter-agency cooperation. The result indicates that effective governance is undermined by a "silo effect," where weak coordination between different government agencies, fragmented institutional mandates leading to overlapping responsibilities, and a lack of platforms for multi-stakeholder dialogue prevent a unified and coherent approach to tackling climate change.

Hypothesis 6: Information & Public Awareness confirmed that this is another key constraint (β = .209, p = -.012). This highlights a dual challenge; a lack of transparency and proactive communication from governing bodies, coupled with limited public awareness and engagement. This suggests that without an informed and engaged community and accessible localized climate data, governance efforts lack both the social mandate and the evidence base needed for success.

Hypothesis 4: Technology & Data Management was the least strong, yet still statistically significant, predictor among the supported hypotheses (β = -.198, p = .015). This finding confirms that a deficit in the "technical toolkit" hinders effective governance. It reflects the challenges posed by limited access to modern climate adaptation technologies, the absence of digital platforms for data collection and monitoring, and weak data-sharing mechanisms between institutions, which are essential for evidence-based decision-making.

Hypothesis 8: Regional Political Instability despite exhibiting a high standardized coefficient (β = -.421), the path was not statistically significant (p = -.124). It does not imply that regional instability is irrelevant. Rather, it suggests that in the perception of the surveyed experts, its

impact on the core, day-to-day functions of UCG is less direct and statistically less predictable than the more chronic, internal institutional weaknesses. This counterintuitive result may imply that local governance processes have developed a degree of resilience or are insulated from these specific external pressures, a point that will be explored in depth through the qualitative data. A visual representation of the full structural model and the tested path relationships is provided by Figure 4.0.3.

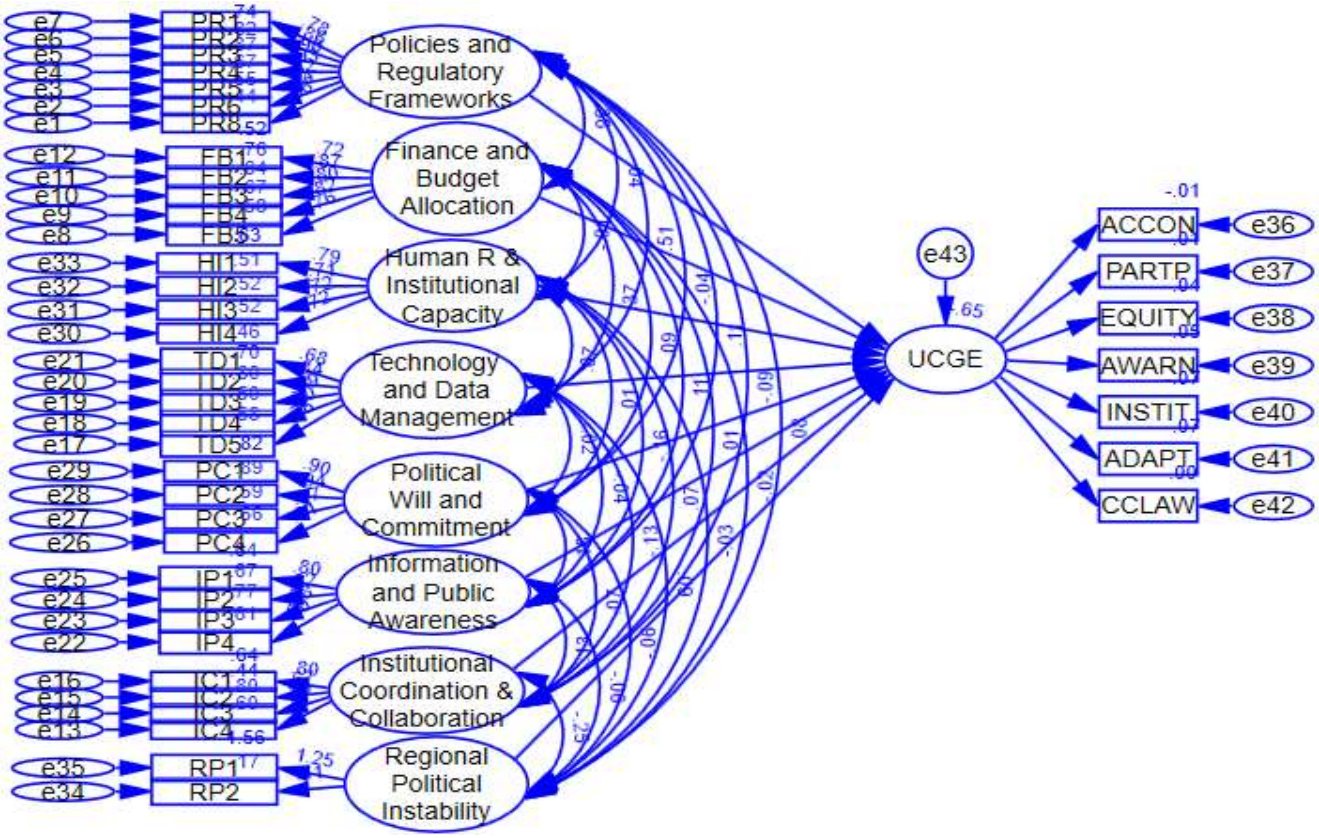


Figure 4.0.3 The Final Structural Equation Model of Institutional Constraints on UCGE

Generally, the SEM analysis has substantiated a robust model where seven of the eight identified institutional constraints are significant predictors of UCGE in Bahir Dar, collectively explaining 65% of its variance. The analysis pinpoints Human Resources and Institutional Capacity as the most critical bottleneck, followed in descending order of influence by the adequacy of Policy Frameworks, Political Will, Financing and Budget Allocation, Institutional Coordination, Information and Public Awareness, and Technology and Data Management. The only non-significant factor, Regional Political Instability, presents a unique paradox that will be explored in the discussion.

4.4. Discussion

This study used a sequential analysis for identifying key institutional constraints to UCGE in Bahir Dar, combining quantitative SEM analysis with qualitative insights. The SEM clearly revealed that seven of eight proposed constraints were significant predictors, jointly explaining 65% of the variance in UCGE. The discussion triangulates these findings with evidence from KIIs and Ethiopia's national climate policy, providing deeper context and explaining how these barriers manifest in practice. The discussion is structured according to the magnitude of the constraints identified in the SEM, from the most to the least influential.

4.4.1. Human Resources and Institutional Capacity

The SEM analysis identified Human Resources and Institutional Capacity as the most potent and significant constraint on effective UCG in Bahir Dar. This finding is not merely statistically significant but points to a fundamental bottleneck for climate action. From the perspective of institutional capacity theory, this robust empirical outcome strongly reinforces the 'human capital' dimension, which posits that the quality and quantity of skilled personnel are foundational for an institution's ability to achieve its objectives, particularly in complex and evolving domains like climate change adaptation..

Qualitative data powerfully clarified this capacity gap, revealing it as profoundly multidimensional. It extends beyond simple staff shortages to encompass critical deficits in specialized expertise, persistent issues with staff retention, and a significant erosion of institutional knowledge. Interviewees consistently highlighted the absence of climate-specific competencies among public officials. For instance, a senior municipal planner observed, ''*most staff working on climate issues are generalists, not climate specialists. They understand general development, but the specifics of climate adaptation, like urban heat island effects or complex hydrological modeling for flood risk, are beyond current capacities*.'' This profound deficiency in technical expertise directly impacts the 'adaptive capacity' component of institutional strength. While similar deficits in translating complex climate data into actionable plans have been reported in larger African cities like Accra and Cape Town (Pasquini, 2020; Simon & Leck, 2015), Bahir Dar's case underscores how this 'generalist' approach, particularly in secondary cities with limited dedicated climate units, fundamentally restricts the institutional ability to move beyond generic environmental management to strategic climate resilience planning.

Furthermore, high staff turnover emerged as a systemic disruptor, severely undermining continuity and institutional memory. A CSO representative explained, ‘‘*we waste time re-establishing relationships*’’ due to frequent staff changes. This sentiment was echoed by a regional environmental agency head who said, ‘‘*just as we train someone on climate vulnerability assessments, they get transferred or leave. We constantly lose institutional memory, forcing us to restart foundational work.*’’ This phenomenon directly impedes the development of cumulative organizational learning and the preservation of institutional memory, both crucial aspects of institutional capacity (Madzwamuse, 2010; Oluwatoyin & Mardikaningsih, 2022). It demonstrates how a lack of sustained human resource development and retention creates a perpetual cycle of foundational knowledge loss, rather than allowing for the iterative learning and adaptation required by a changing climate. Studies in Addis Ababa (Addis et al., 2022) confirm challenges in skilled personnel, but Bahir Dar's experience accentuates the vulnerability of smaller, rapidly growing cities where even modest turnover can destabilize climate governance efforts.

Compounding this, capacity-building efforts are often inconsistent and externally driven, with a government official noting that ‘‘*trainings depend on external projects*.’’ This dependency highlights a critical vulnerability in the 'resource mobilization' and 'sustainability' dimensions of institutional capacity, where externally imposed, discontinuous interventions fail to foster intrinsic and enduring institutional competence (Muchiri & Opiyo, 2022). Such fragmented, project-based training, rather than integrated capacity development, limits the institutionalization of climate expertise. The situation in Bahir Dar, while mirroring national-level challenges acknowledged by NAP-ETH (FDRE, 2019), therefore deepens the theoretical understanding of institutional capacity by illustrating how a weak human resource base, coupled with instability and externally-driven, non-integrated training, creates a chronic and self-reinforcing constraint on institutional effectiveness. This suggests that for rapidly urbanizing secondary cities, strengthening institutional capacity requires a paradigm shift from reactive, project-specific interventions to holistic, long-term human resource strategies that prioritize retention, specialized skill development, and endogenous learning to truly embed climate governance capabilities.

4.4.2. Deficiencies in Policy and Regulatory Frameworks

Policies and Regulatory Frameworks emerged as the second most significant barrier to effective UCG in Bahir Dar. This aligns with extensive literature identifying a persistent

policy-implementation gap in environmental governance (Frank et al., 2018). In Bahir Dar, this gap does not reflect a complete absence of policy, but rather what interviewees described as a "*hollow core*", a state where policies exist on paper but lack local specificity, operational integration, and most critically enforcement. From the perspective of Institutional Capacity Theory, this represents a profound disconnect between formal policy and operational institutional capacity. The structural and normative pillars of the governance framework are present, but they lack the functional mechanisms to be effective.

A primary reason for this "hollow core" is the failure of multi-level governance in tailoring policy to local contexts. A city planning expert articulated this frustration, stating, ''*Our national guidelines are good in principle, but when we try to apply them to Bahir Dar's unique lakeside ecosystem or informal settlements, they are too broad and not tailored to our realities.*'' This challenge of downscaling national policies is common in the Global South (Betsill & Bulkeley, 2005; Mukheibir & Ziervogel, 2007) and resonates strongly with experiences in Ghanaian cities, where centralized climate policies weaken due to a lack of local tailoring and enforcement (Boateng, 2023). However, Bahir Dar's case pushes this debate further by highlighting a potential secondary city capacity deficit. Unlike the capital, Addis Ababa, which may possess greater resources and political influence to adapt or develop specific policies, Bahir Dar appears to lack the institutional autonomy and technical capacity to effectively translate broad national mandates into locally actionable regulations. This suggests that the policy-implementation gap is not uniform, but widens significantly in urban centers outside the primary national hub.

Where regulations do exist, implementation is weak. A local government official acknowledged that "*existing strategies suffer from weak enforcement mechanisms at the local level*", allowing violations to go unchecked. The real-world consequence was starkly illustrated by a community elder from a flood-prone area, who stated, ''*we see new buildings going up in drainage paths, despite rules against it. The officials come, inspect, but no change is visible. Every rainy season, our homes flood again*.'' This powerful testimony was directly corroborated by our own field observations, which documented multiple instances of new construction encroaching on natural and man-made drainage channels in direct violation of the city's master plan.

Furthermore, observations during rainfall events confirmed that these compromised drainage systems were quickly overwhelmed, leading to localized flooding exactly as described by

community members. This goes beyond a simple lack of capacity; it signifies a failure of the state's regulatory function, a core component of institutional effectiveness (Tosun & Leininger, 2017; Willis et al., 2022). Theoretically, this persistent non-compliance and lack of state response erode institutional legitimacy and public trust, key elements of social capital that are vital for collective climate action. The community's perception that "*no change is visible*" is not just a statement of fact but an indictment of institutional credibility.

This situation contradicts the first strategic priority of Ethiopia's NAP-ETH "Mainstreaming climate change adaptation into development policies, plans and strategies" at all levels (FDRE, 2019). The "*hollow core*" in Bahir Dar, therefore, offers a critical theoretical insight, effective UCG is contingent not merely on the existence of policies, but on an institution's integrated capacity for both contextualization (adapting broad rules to local realities) and enforcement (ensuring compliance). The, findings suggest these specific capacities are acutely underdeveloped in rapidly urbanizing secondary cities, presenting a significant and potentially widening gap in national climate resilience strategies.

4.4.3. Political Will and Leadership Instability

The analysis identified political will and commitment as the third most influential constraint to UCGE in Bahir Dar. This finding highlights the centrality of the political dimension of Institutional Capacity Theory, which recognizes leadership as a critical driver for prioritizing, legitimizing, and sustaining governance actions (IPCC, 2023; Moore et al., 2024). However, qualitative data reveals that in Bahir Dar, this political capacity is not only weak but also highly inconsistent, reactive, and personalized, with leadership turnover acting as a systemic ''*reset button.*''

The reactive nature of political engagement was a recurring theme. A long-serving government environmental officer remarked, ''*climate issues gain attention during crisis moments like flooding or water shortages, but after the immediate crisis passes, the sustained leadership and budget commitment often disappear*.'' This governance by disaster (Ansah et al., 2024; Cobbinah & Finn, 2023) represents a significant theoretical constraint on institutional capacity. It locks the governance system into a state of perpetual short-term crisis management, or coping capacity, fundamentally preventing the strategic, long-term planning necessary to build genuine adaptive capacity and resilience.

Leadership turnover emerged as the most destabilizing force, directly undermining the continuity essential for institutional capacity building. A private sector respondent explained,

"*When a mayor or bureau head changes, everything resets. There's no predictability. We've seen climate projects, even those with external funding, lose momentum or be re-prioritized entirely with a new administration, wasting previous efforts and trust.*" While high political turnover is a known challenge across African cities (Allarané et al., 2024; Boateng, 2023), Bahir Dar's case as a secondary city offers a crucial insight; the impact of such instability may be felt even more acutely where institutional structures are less entrenched and a single leader's influence is more concentrated. The "*reset button*" does not just stall projects; it actively erodes institutional memory and undermines the trust required for multi-stakeholder partnerships.

Ultimately, the perception that governance is personality-driven, not policy-driven signifies a critical failure of institutionalization. Theoretically, this means that climate governance capacity resides within individuals rather than being embedded in the formal rules, procedures, and culture of the institutions themselves. This makes any progress fragile and short-lived. This dynamic is the very antithesis of the NAP-ETH objective to ''institutionalize climate adaptation to ensure continuity and consistency'' (FDRE, 2019). Therefore, the findings contribute to the theoretical debate by demonstrating that in contexts of high political turnover, a lack of institutionalized climate policy creates a vicious cycle; weak political will prevents the institutionalization of climate action, and this lack of institutionalization makes governance efforts entirely vulnerable to the next political reset. Addressing this dynamic is essential for transitioning from reactive, personality-driven governance to the durable, systematized climate leadership required for long-term urban resilience.

4.4.4. Financing and Budget Allocation

Financing and Budget Allocation was identified as a significant constraint to UCGE in Bahir Dar, revealing critical weaknesses in the financial capacity and resource mobilization dimensions of the city's institutional framework. The core challenge is not merely a lack of funds but a system of unstable, unsustainable, and non-dedicated funding. This issue is primarily driven by two interconnected problems; a heavy dependence on external donor grants and a persistent lack of domestic budgetary prioritization.

First, the reliance on "project-based donor grants" creates profound financial instability. As one government official candidly noted, "*When donors delay or withdraw, key programs to enhance drainage or promote green infrastructure simply stall... We lack the internal funds to keep them going*." This aligns with critiques of donor-driven finance (Kaklauskaite & Streimikiene, 2024) and is a common pattern in Sub-Saharan African cities (Mungai et al.,

2022). However, beyond merely confirming this pattern, our findings suggest a deeper theoretical implication; this dependency locks the urban governance system into a reactive and contingent posture. It stifles the development of autonomous, long-term financial planning, a core tenet of robust institutional capacity, and instead promotes a short-term, project-chasing mentality that is inherently unsustainable and misaligned with local strategic needs.

Second, this external reliance is exacerbated by a failure to institutionalize climate action within domestic budgetary processes. Officials admitted, ‘‘*the climate budget is not specifically protected*,’’ with a senior official elaborating on the ‘‘*intense internal budget battle*s’’ where climate projects are often sacrificed for more immediate development needs like roads and housing. Theoretically, this demonstrates that climate governance has not been successfully mainstreamed or legitimized as a core, non-negotiable municipal function. Instead, it is treated as a discretionary or secondary concern, making it highly vulnerable to political and economic pressures. This marginalization within the budgeting process is a powerful indicator of weak institutionalization, where climate action remains an add-on rather than a fundamental component of urban development strategy.

Bahir Dar’s situation, therefore, offers a critical insight that pushes the theoretical debate forward. The financial constraint is a symptom of a deeper institutional failure to embed climate action within the city's core fiscal and political machinery. Document analysis of NAP-ETH confirms that establishing ‘‘effective and sustainable funding mechanisms’’ is a high-level national priority (FDRE, 2019). However, empirical findings from Bahir Dar demonstrate a profound disconnect between this national ambition and municipal reality. Achieving this goal requires more than just securing new funding streams. This is essential to gain the fiscal autonomy required for building genuine, long-term institutional capacity for urban climate resilience, a challenge clearly identified in the NAP-ETH but not yet overcome at the local level.

4.4.5. Institutional Coordination and Collaboration

Institutional Coordination and Collaboration emerged as a significant constraint on UCGE. This finding echoes the wider literature that frames climate change as a complex challenge requiring cross-sectoral integration and multi-level coordination (Bremer et al., 2021). In Bahir Dar, however, interviews revealed a fragmented governance structure marked by uncoordinated operations and overlapping mandates. A regional official observed, “*Responsibilities overlap across departments*”, highlighting the absence of clearly defined

roles. This lack of clear demarcation often leads to inaction or duplication of effort, particularly on cross-cutting climate issues that require multiple departments. This institutional ambiguity is a common obstacle in climate governance, where weak mandates and lack of centralized coordination allow climate issues to be overlooked (McNaught, 2024). This "silo effect" is a pervasive problem in many developing cities, where institutional fragmentation often prevents holistic approaches to complex issues like climate change (Castán-Broto, 2020).

Stakeholder engagement is also undermined by the absence of formalized coordination platforms. One government respondent noted that meetings are "*project-specific*", while a CSO representative described the process as "*not well-organized*". This mirrors concerns in the literature that one-off consultations are insufficient for sustained governance, and that permanent, inclusive forums are essential for joint decision-making and accountability (Ross et al., 2021). A private sector interviewee appropriately summarized the gap as "*There's no formal platform, no regular forum for us to engage with the city on climate plans. We are only consulted when a specific project needs our contribution, which feels superficial*".

These governance shortcomings contrast sharply with the principles of Ethiopia's NAP-ETH, which emphasizes "participation" and "coherent interventions" (FDRE, 2019). The study underscores the difficulty of operationalizing these principles locally, where institutional barriers remain deeply entrenched, a pattern also observed in the challenges of multi-level governance in other East African urban contexts.

4.4.6. Information, Awareness, and Transparency

Information and Public Awareness emerged as a significant barrier to effective UCG. This finding aligns with studies emphasizing that transparency and public engagement are not ancillary, but central to effective, inclusive climate governance (Ali & Kamraju, 2025; Olazabal & Ruiz De Gopegui, 2021). In Bahir Dar, this challenge manifests as both a lack of institutional communication and limited citizen involvement. Community members reported feeling uninformed, with one stating, "*If such policies exist, they're not communicated clearly to the public. We often only hear about issues when there's a problem, not about prevention or plans*". This reflects a top-down, expert-driven governance style that undermines public understanding and engagement. As literature suggests, without accessible information, building long-term civic support for climate action becomes nearly impossible (Khatibi et al., 2021). Similar challenges in public awareness and engagement are commonly cited across African cities, where top-down approaches often fail to effectively translate climate

information into locally relevant and actionable knowledge (Muchiri & Opiyo, 2022; Simon & Leck, 2015).

Moreover, a lack of openness makes this issue worse. Officials admitted that "*budgets are discussed in closed sessions*", while CSOs reported having to file "*freedom-of-information requests to get basic data*". This opacity fuels public distrust and limits the ability of civil society to hold government accountable for climate-related expenditures and actions. These practices reduce transparency and erode public trust, raising risks of elite capture and excluding vulnerable communities from critical decisions. Ultimately, the disconnect between governors and the governed in Bahir Dar weakens the social legitimacy and accountability of climate governance, barriers that must be addressed to build more participatory and resilient urban systems, highlighting a critical need for enhanced civic participation in climate action planning.

4.4.7. Technology and Data Management

Though the least statistically strong of the significant predictors, Technology and Data Management remains a critical barrier to effective UCG. The KIIs reveal a system constrained by outdated, fragmented data practices in an era that demands real-time, digital decision-making. This mirrors findings from broader research on Africa's persistent "digital divide" in climate services (Pan et al., 2022; Shaji & Kumar, 2025).

The statement "*Most data are paper-based or sit in isolated systems*" from regional government official exemplifies the analog reality, resulting in operational inefficiencies and limited data integration. This gap has real consequences, for instance, community members reported relying on "*rumors or seeing the flood rising*" instead of official early warnings. A woman living near a riverbank elaborated, ''*we don't get any official alerts for heavy rain or rising water. We just watch the river, or hear from neighbors, and then react when the water is already in our streets*.'' This illustrates the critical problem where climate information fails to reach end-users in time. This issue of fragmented, inaccessible, or non-digitized climate data is a widespread impediment to effective urban climate governance across many African cities, where investment in robust data infrastructure and management systems often lags (Pasquini, 2020; Simon & Leck, 2015).

Private sector actors face similar challenges. A construction firm owner noted, ''we build according to the existing master plan, but without access to up-to-date climate projections or vulnerability maps, we are effectively building blind to future risks like extreme heat or altered rainfall patterns.'' This reflects a disconnect between urban development and climate data,

increasing long-term risk. CSOs also stressed the need to "*democratize*" climate data and translate it into usable formats, a call echoed in literature advocating for accessible, localized, and decision-ready data (Mbah et al., 2021). Without improved digital infrastructure, real-time monitoring, and participatory data systems, evidence-based governance in Bahir Dar will remain elusive hindering both adaptive capacity and long-term climate resilience, underscoring a continent-wide need for targeted investment in climate information systems.

4.4.8. The Paradox of Regional Political Instability

One of the most revealing findings from the SEM was the non-significant relationship between Regional Political Instability and UCGE ($p = .124$). This statistical insignificance contrasts sharply with the qualitative data, where government official respondents consistently described instability as highly disruptive. A city administrator grimly recounted, *''during periods of regional unrest, we've seen climate adaptation projects suspended indefinitely, funds diverted, and international partners become hesitant to commit resources. It's like pressing a pause button on all progress*.'' This aligns with studies on climate governance in fragile contexts, which describe instability as a threat multiplier that undermines implementation but often acts through indirect or non-linear pathways (Sändig et al., 2024). For instance, experiences in cities within the Central African region demonstrate how political disruptions, while not always directly weakening institutional frameworks, severely impede resource allocation and project continuity for climate initiatives (Allarané et al., 2024).

Survey respondents may have classified this disruption recognizing instability as an external force separate from institutional structures they directly assess. In effect, political crises may not weaken policy frameworks, but they can halt their implementation entirely. As one official put it, instability doesn't alter the "*software*" of governance it shuts down the "*hardware*." This underscores the strength of the mixed-methods approach. A purely quantitative analysis might have dismissed instability as irrelevant; a purely qualitative one might have overstated its direct role. Together, they reveal that while instability may not statistically predict daily governance performance, it remains a critical contextual threat capable of striking climate efforts altogether, a key insight for policymaking in volatile urban environments, particularly in regions prone to social and political unrest.

4.5. Conclusion

This study rigorously examined the institutional constraints affecting UCG Effectiveness (UCGE) in Bahir Dar City. The strength of this study lies in its focus on a rapidly growing

secondary Ethiopian city; a context critically under-examined in climate governance literature and its use of a sequential explanatory mixed-methods approach. By integrating the investigative power of SEM with the contextual depth of thematic analysis, it provide a uniquely multi-layered and nuanced understanding of how institutional factors shape urban climate responses.

The SEM analysis revealed that seven of the eight hypothesized constraints significantly influenced UCGE, collectively explaining 65% of its variance. The prominence of Human Resources and Institutional Capacity as the most influential predictor, closely followed by deficiencies in Policy and Regulatory Frameworks and Political Will empirically reinforces the core tenets of Institutional Capacity. These findings were profoundly enriched by qualitative data, which illuminated the practical manifestations of these barriers through structural challenges such as high staff turnover, weak policy enforcement, reactive leadership, and fragmented coordination. Furthermore, the qualitative finding that Regional Political Instability acts as a latent, acute disruptor, despite its statistical non-significance in the SEM, offers a critical nuance to theories of institutional resilience, distinguishing between chronic internal dysfunctions and acute external shocks.

Theoretically, this study's primary contribution is the empirical disaggregation and validation of the multi-dimensional nature of institutional capacity for UCG in a secondary city context. It moves beyond generic claims of 'weak institutions' to provide a granular diagnosis of the most critical components of capacity, from human capital to political commitment. By empirically substantiating concepts like the 'hollow core' of policies (where rules exist without enforcement) and the systemic 'reset button' of leadership instability, the study offers a refined, evidence-based understanding of how and why institutional capacities falter, providing a robust and replicable analytical framework for other emerging cities.

Practically, our findings not only confirm widely reported governance challenges but critically contextualize them within Ethiopia's evolving climate policy landscape, offering direct empirical validation for priorities set in the NAP-ETH. However, translating these findings into policy requires moving from broad acknowledgements to concrete, actionable steps. For Bahir Dar and similar cities, we recommend that policymakers 1) develop a municipal climate expertise retention program with professional development incentives and specialized training to build and maintain essential human capital. 2) Institutionalize climate action through legally-binding municipal climate action plans and create permanent, cross-departmental climate task

forces that are empowered to survive leadership changes. 3) Establish dedicated municipal climate funds, potentially seeded by local environmental levies or public-private partnerships, to create ring-fenced budgets and reduce donor dependency. 4) Formalize a permanent multi-stakeholder climate governance platform to ensure continuous and structured engagement between government, civil society, the private sector, and community groups.

Overall, this study demonstrates the critical importance of aligning national climate ambitions with durable, localized institutional capabilities. By offering a theoretically informed and empirically grounded diagnosis, this study provides valuable comparative insights and a clear pathway for other emerging cities across Ethiopia and Sub-Saharan Africa striving to build effective and resilient urban climate governance.

4.5.1. Limitations

The quantitative analysis is based on a sample of 162 experts. While some general guidelines in SEM literature suggest a sample size of 200 or more for stable model estimation, this study's sample should be interpreted in the context of its specific design. The research did not employ random sampling from a large population; rather, it conducted a census of a small, highly specialized, and purposively defined population namely, all available experts directly involved in the UCG process in Bahir Dar. For the research questions at hand, capturing the complete perspective of this unique expert group was deemed methodologically more robust than obtaining a larger, less-informed sample. Furthermore, the stability of the final SEM model, evidenced by the strong goodness-of-fit indices and significant parameter estimates, suggests that the sample size was ultimately sufficient for the complexity of the model and the relationships tested.

REFRENCES

Addis, T. L., Birhanu, B. S., & Italemahu, T. Z. (2022). Effectiveness of Urban Climate Change Governance in Addis Ababa City, Ethiopia. *Urban Science*, *6*(3). https://doi.org/10.3390/urbansci6030064

Adigeh, D. T., & Abebe, B. G. (2023). The Practice of Peri-Urban Land Acquisition by Expropriation for Housing Purposes and the Implications: The Case of Bahir Dar, Ethiopia. *Urban Science*, *7*(2). https://doi.org/10.3390/urbansci7020041

Ali, M. A., & Kamraju, M. (2025). Accountability, Transparency, and Adaptation Strategies. *Global Climate Governance*, 135–154. https://doi.org/10.1007/978-981-96-2727-1_6

Allarané, N., Atchadé, A. J., N'Dilbé, T. R., Azagoun, V. V. A., & Hetcheli, F. (2024). Integrating Climate Change Adaptation Strategies into Urban Policies for Sustainable

City Resilience: Barriers and Solutions in the Central African City of N'Djaména. *Sustainability*, *16*(13), 5309. https://doi.org/10.3390/SU16135309

Ansah, E. W., Amoadu, M., Obeng, P., & Sarfo, J. O. (2024). Climate change, urban vulnerabilities and adaptation in Africa: a scoping review. *Climatic Change*, *177*(4), 1–20. https://doi.org/10.1007/S10584-024-03711-8/METRICS

Appelhans, N. (2017). Urban Planning and Everyday Urbanisation A Case Study on Bahir Dar, Ethiopia. In *Dissertation*. https://doi.org/10.1515/9783839437155

Asmamaw, M., & Debie, E. (2023). Characterizing groundwater quality for a safe supply of water using WQI and GIS in Bahir Dar city, northwest Ethiopia. *Water Practice and Technology*, *18*(4), 859–883. https://doi.org/10.2166/wpt.2023.046

Bahir Dar City Structural Plan Preparation Project Office. (2020). *Population Study Report*.

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

Betsill, M. M., & Bulkeley, H. (2005). Cities Protecting the Climate: the Local Dimension of Global Environmental Governance. *Advances in the Economics of Environmental Resources*, *5*, 189–213. https://doi.org/10.1016/S1569-3740(05)05009-1

Birara, H., Pandey, R. P., & Mishra, S. K. (2020). Projections of future rainfall and temperature using statistical downscaling techniques in Tana Basin, Ethiopia. *Sustainable Water Resources Management*, *6*(5), 1–17. https://doi.org/10.1007/S40899-020-00436-1/FIGURES/9

Boateng, A. K. (2023). Localising centralised climate policies in Ghana: insights from 3 local governments. *Urban Research and Practice*, *16*(3), 470–482. https://doi.org/10.1080/17535069.2022.2129173;CTYPE:STRING:JOURNAL

Braun, V., & Clarke, V. (2006). Thematic analysis revised. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Bremer, S., Glavovic, B., Meisch, S., Schneider, P., & Wardekker, A. (2021). Beyond rules: How institutional cultures and climate governance interact. *Wiley Interdisciplinary Reviews: Climate Change*, *12*(6), e739. https://doi.org/10.1002/WCC.739;WGROUP:STRING:PUBLICATION

Castán Broto, V., & Westman, L. K. (2020). Ten years after Copenhagen: Reimagining climate change governance in urban areas. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(4), e643. https://doi.org/10.1002/WCC.643

Cobbinah, P. B., & Finn, B. M. (2023). Planning and Climate Change in African Cities: Informal Urbanization and 'Just' Urban Transformations. *Journal of Planning Literature*, *38*(3), 361–379. https://doi.org/10.1177/08854122221128762

Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches. In *SAGE Publications Asia-Pacific Pte. Ltd* (Third, Vol. 4, Issue 11). SAGE Publications Ltd. https://doi.org/10.1128/microbe.4.485.1

CSA. (1984). The 1984 Population and Housing Census of Ethiopia. In *Central Statistical Authority* (Issue December). http://www.csa.gov.et/surveys/Population and Housing census/ETH-pop-2007/survey0/data/Doc/Reports/National_Statistical.pdf

Dadi, T. T. (2018). *The influence of land management on the prevalence of informal settlement and its implication for environmental management in Bahir Dar city, Ethiopia*.

Debebe, F. A., & Miteku, M. N. (2023). Effects of land use/land cover Changes on land surface Temperature and Agricultural lands in Bahir Dar Zuria Woreda. *Journal of Urban Development Studies*, *3*(1).

Digafe, B. M., Adam, A. G., & Shibeshi, G. B. (2024). Evaluation of the urban Land use plan's effectiveness in achieving resource efficiency: the case of Bahir Dar city-Ethiopia. *International Journal of Urban Sustainable Development*, *16*(1), 17–34. https://doi.org/10.1080/19463138.2024.2303503

Dodman, D., Hayward, B., Pelling, M., Broto, V. C., & Chow, W. T. L. (2022). *Cities, settlements and key infrastructure*. 907–1040.

Domorenok, E., Graziano, P., & Polverari, L. (2021). Introduction: policy integration and institutional capacity: theoretical, conceptual and empirical challenges. *Policy and Society*, *40*(1), 1–18. https://doi.org/10.1080/14494035.2021.1902058

FDRE. (2019). *Ethiopia's Climate Resilient Green Economy Strategy. National Adaptation Plan* (Issue May).

Folke, C., Hahn, T., & Norberg, J. (2005). Adaptive governance of social-ecological systems (RRH) Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*(1), 441–473.

Frank, T., Michael, B., Karlee, J., Jonathan, E., Heidi, T., Åsa Gerger, S., Guoyi, H., John, F., & Darin, W. (2018). Transforming Development and Disaster Risk. *Sustainability*, *10*(1458). http://dx.doi.org/10.3390/su10051458

Gedefaw, M., Yan, D., Wang, H., Qin, T., & Wang, K. (2019). Analysis of the Recent Trends of Two Climate Parameters over Two Eco-Regions of Ethiopia. *Water*, *11*(1), 161. https://doi.org/10.3390/W11010161

Getachew, B., & Manjunatha, B. R. (2021). Climate change projections and trends simulated from the CMIP5 models for the Lake Tana sub-basin, the Upper Blue Nile (Abay) River Basin, Ethiopia. *Environmental Challenges*, *5*, 100385. https://doi.org/10.1016/J.ENVC.2021.100385

Getu, K., & Bhat, H. G. (2024). Quantifying Spatio-temporal dynamics of land surface temperature for the rapidly growing city of Bahir Dar, Northwest Ethiopia using multidated Landsat data. *Physics and Chemistry of the Earth*, *134*(August 2022), 103543. https://doi.org/10.1016/j.pce.2024.103543

Getu, K., & Gangadhara Bhat, H. (2024). Application of geospatial techniques and binary logistic regression model for analyzing driving factors of urban growth in Bahir Dar city, Ethiopia. *Heliyon*, *10*(3), e25137. https://doi.org/10.1016/j.heliyon.2024.e25137

Hair, J. F. (2011). Multivariate Data Analysis: An Overview. *International Encyclopedia of Statistical Science*, 904–907. https://doi.org/10.1007/978-3-642-04898-2_395

Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2019). Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. *Regional Environmental Change*, *19*(3), 791–805. https://doi.org/10.1007/S10113-018-1329-3/TABLES/2

IPCC. (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Repor. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *IPCC*. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Kaklauskaite, U., & Streimikiene, D. (2024). Climate justice from the lens of sustainable development. *Sustainable Development*, *32*(6), 6788–6800. https://doi.org/10.1002/SD.3062

Khatibi, F. S., Dedekorkut-Howes, A., Howes, M., & Torabi, E. (2021). Can public awareness, knowledge and engagement improve climate change adaptation policies? *Discover Sustainability*, *2*(1), 1–24. https://doi.org/10.1007/S43621-021-00024-Z/FIGURES/5

Kindu, M., Angelova, D., Schneider, T., Döllerer, M., Teketay, D., & Knoke, T. (2020). Monitoring of Urban Growth Patterns in Rapidly Growing Bahir Dar City of Northwest Ethiopia with 30 year Landsat Imagery Record. *ISPRS International Journal of Geo-Information*, *9*(9), 548. https://doi.org/10.3390/IJGI9090548

Kuma, G. H., Fufa Feyessa, F., & Adugna Demissie, T. (2022). Local climate change indications: Historical trends, multi-model projections and implications in Bilate Catchment, Southern Ethiopia. *IOP Conference Series: Earth and Environmental Science*, *1016*(1). https://doi.org/10.1088/1755-1315/1016/1/012030

Madzwamuse, M. (2010). Drowning Voices: The Climate Change Discourse in South Africa. *Heinrich-Böll-Foundation*.

Mbah, M., Ajaps, S., & Molthan-Hill, P. (2021). A systematic review of the deployment of indigenous knowledge systems towards climate change adaptation in developing world contexts: Implications for climate change education. *Sustainability*, *13*(9), 4811. https://doi.org/10.3390/SU13094811/S1

McNaught, R. (2024). The application of collaborative governance in local level climate and disaster resilient development – A global review. *Environmental Science & Policy*, *151*, 103627. https://doi.org/10.1016/J.ENVSCI.2023.103627

Menashe, A., & Bocquier, P. (2021). Urbanization Is No Longer Driven by Migration in Low- and Middle-Income Countries (1985–2015). *Population and Development Review*, *47*(3), 639–663. https://doi.org/10.1111/PADR.12407

Moore, B., Geese, L., Kenny, J., Dudley, H., Jordan, A., Prados Pascual, A., Lorenzoni, I., Schaub, S., Enguer, J., & Tosun, J. (2024). Politicians and climate change: A systematic review of the literature. *Wiley Interdisciplinary Reviews: Climate Change*, *15*(6), e908. https://doi.org/10.1002/WCC.908

Muchiri, C. N., & Opiyo, R. O. (2022). Community adaptation strategies in Nairobi informal settlements: Lessons from Korogocho, Nairobi-Kenya. *Frontiers in Sustainable Cities*, *4*, 932046. https://doi.org/10.3389/FRSC.2022.932046/BIBTEX

Mukheibir, P., & Ziervogel, G. (2007). Developing a Municipal Adaptation Plan (MAP) for climate change: the city of Cape Town. *Environment and Urbanization*, *19*(1), 143–158. https://doi.org/10.1177/0956247807076912

Nannawo, A. S., Kumar Lohani, T., & Eshete, A. A. (2017). Envisaging the actual evapotranspiration and elucidating its effects under climate change scenarios on agrarian

lands of bilate river basin in Ethiopia. *Heliyon*, *8*(e10368). https://doi.org/10.1016/j.heliyon.2022.e10368

Nhamo, L., Rwizi, L., Mpandeli, S., Botai, J., Magidi, J., Tazvinga, H., Sobratee, N., Liphadzi, S., Naidoo, D., Modi, A. T., Slotow, R., & Mabhaudhi, T. (2021). Urban nexus and transformative pathways towards a resilient Gauteng City-Region, South Africa. *Cities*, *116*, 103266. https://doi.org/10.1016/J.CITIES.2021.103266

Olazabal, M., & Ruiz De Gopegui, M. (2021). Adaptation planning in large cities is unlikely to be effective. *Landscape and Urban Planning*, *206*, 103974. https://doi.org/10.1016/J.LANDURBPLAN.2020.103974

Oluwatoyin, F., & Mardikaningsih, R. (2022). Community Adaptation Strategy to Climate Change Based on Socio-Cultural Perspective. *Journal of Social Science Studies*, *2*(1), 167–172. https://jos3journals.id/index.php/jos3/article/view/96

Pan, S. L., Carter, L., Tim, Y., & Sandeep, M. S. (2022). Digital sustainability, climate change, and information systems solutions: Opportunities for future research. *International Journal of Information Management*, *63*, 102444. https://doi.org/10.1016/J.IJINFOMGT.2021.102444

Pande, C. B., Moharir, K. N., Varade, A. M., Abdo, H. G., Mulla, S., & Yaseen, Z. M. (2023). Intertwined Impacts Of Urbanization And Land Cover Change On Urban Climate And Agriculture In Aurangabad City (MS), India Using Google Earth Engine Platform. *Journal of Cleaner Production*, *422*, 138541. https://doi.org/10.1016/J.JCLEPRO.2023.138541

Pasquini, L. (2020). The urban governance of climate change adaptation in least-developed African countries and in small cities: the engagement of local decision-makers in Dar es Salaam, Tanzania, and Karonga, Malawi. *Climate and Development*, *12*(5), 408–419. https://doi.org/10.1080/17565529.2019.1632166

Rivas, W., Santiago, J., Carlson, S., & Dunn, J. (2023). Urbanization and Environmental Degradation in African Cities. *Journal of African Development*, *4*, N/A-N/A. https://doi.org/10.61336/JAD/25-04-01

Ross, A., Van Alstine, J., Cotton, M., & Middlemiss, L. (2021). Deliberative democracy and environmental justice: evaluating the role of citizens' juries in urban climate governance. *Local Environment*, *26*(12), 1512–1531. https://doi.org/10.1080/13549839.2021.1990235

Sändig, J., Dalmer, N., Ide, T., & Vogler, A. (2024). From climate conflicts to environmental peacebuilding: Exploring local dimensions. *Environment and Security*, *2*(1), 3–20. https://doi.org/10.1177/27538796241231090

Seyoum, S. (2014). The Growth of Bahir Dar: 1941-1974. *Ethiopian Journal of Development Research*, *36*(2), 83–109.

Shaji, M., & Kumar, A. (2025). Digital Pathways to Sustainability: Integrating Technology and Innovation for a Greener Future. *IGI Global Scientific Publishing*, 1–38. https://doi.org/10.4018/979-8-3693-9909-5.CH001

Simon, D., & Leck, H. (2015). Understanding climate adaptation and transformation challenges in African cities. *Current Opinion in Environmental Sustainability*, *13*, 109–116. https://doi.org/10.1016/J.COSUST.2015.03.003

Solorio, I. (2021). Leader on paper, laggard in practice: policy fragmentation and the multi-level paralysis in implementation of the Mexican Climate Act. *Climate Policy*, *21*(9), 1175–1189. https://doi.org/10.1080/14693062.2021.1894084

Squires, V. R., & Gaur, M. K. (2020). Food security and land use change under conditions of climatic variability: A multidimensional perspective. *Springer International*, 1–355. https://doi.org/10.1007/978-3-030-36762-6

Tashakkori, A., & Teddlie, C. (2003). Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International Journal of Social Research Methodology*, *6*(1), 61–77. https://doi.org/10.1080/13645570305055

Tessema, M. W. (2017). Impact of Urban Expansion on Surrounding Peasant Land the Case of Boloso Sore Woreda, Areka Town, SNNPR, Ethiopia. *Global Journal of Human-Social Science*, *17*(2), 1–15.

Tosun, J., & Leininger, J. (2017). Governing the Interlinkages between the Sustainable Development Goals: Approaches to Attain Policy Integration. *Global Challenges*, *1*(9), 1700036. https://doi.org/10.1002/GCH2.201700036

UNDP. (2011). Governance Principles, Institutional Capacity and Quality. In *Towards sustaining MDG progress (Chapter 8)*. UNDP.

UNECA. (2018). World Urbanization Prospects 2018 Highlights. *Department of Economic and Social Affairs*.

UNESCO. (2015). Unlocking the Potential of Urban Communities. Case Studies of Twelve Learning Cities. In *National Institute for Lifelong*. https://files.eric.ed.gov/fulltext/ED564060.pdf

Willis, R., Curato, N., & Smith, G. (2022). Deliberative democracy and the climate crisis. *Wiley Interdisciplinary Reviews: Climate Change*, *13*(2). https://doi.org/10.1002/WCC.759

World Bank. (2011). Institutional Capacities and Their Contributing Characteristics for Institutional Diagnostics, Program Design and Results Management. In *World Bank Institute*. https://documents1.worldbank.org/curated/en/249381467986349471/pdf/80636-WP-Institutional-Capacities-Feb-11-Box-377295B-PUBLIC.pdf

World Bank. (2023). Elements That Enhance Institutional Capacity Development in World Bank Projects and Country Partnerships in Sub-Saharan Africa. In *World Bank Group*.

Wubie, A. M., de Vries, W. T., & Alemie, B. K. (2020). A Socio-Spatial Analysis of Land Use Dynamics and Process of Land Intervention in the Peri-Urban Areas of Bahir Dar City. *Land*, *9*(11), 445. https://doi.org/10.3390/LAND9110445

CHAPTER 5

5. ASSESSING LIVELIHOOD VULNERABILITY OF PERI-URBAN FARMERS TO URBAN EXPANSION AND CLIMATE VARIABILITY IN BAHIR DAR, ETHIOPIA

Based on publication:

Melese, M., Anteneh, M., & Bantigegn, S. (2026). Assessing Livelihood Vulnerability of Peri-Urban Farmers to Urban Expansion and Climate Variability in Bahir Dar, Ethiopia, Geo: Geography and Environment, Wiley. https://doi.org/10.1002/geo2.70096

Abstract

Livelihood vulnerability assessments in developing nations have traditionally focused on rural agrarian settings, analyzing environmental shocks through a strictly hydro-meteorological lens. However, peri-urban areas are critical socio-spatial interfaces where state-led urban encroachment acts as a concurrent, compounding macro-stressor alongside climate variability. Arguing against standard, climate-only frameworks, this study demonstrates that peri-urban vulnerability is a multi-stressor outcome of both climatic and rapid land-use transformations. Employing a mixed-methods approach, the study utilized the Livelihood Vulnerability Index (LVI) framework with data from a survey of 345 households, complemented by qualitative insights from Focus Group Discussions (FGD). The LVI-IPCC results (on a scale of -1 to +1) reveal a state of moderate vulnerability (mean = -0.029), representing a fragile equilibrium where limited adaptive capacity barely offsets rising exposure. High sensitivity (0.586) emerged as the most acute dimension, driven by the interaction of urban encroachment (eroding the natural asset base) and climate variability (undermining crop productivity). This dual pressure acts as a vulnerability multiplier, threatening long-term sustainability by trapping households in high-risk subsistence cycles. While farmers possess strong human (0.628) and social capital (0.554), their adaptive capacity is severely constrained by deficits in physical and financial capital, particularly the lack of rural electrification and income diversification (0.428). The study concludes that traditional resilience is being systematically overwhelmed. Actionable recommendations include implementing participatory land-use zoning to protect agricultural buffers, institutionalizing micro-insurance schemes for crop loss, and providing vocational training to youth to reduce dependence on shrinking farmland and ensure long-term peri-urban resilience.

Keywords: Climate Variability, Livelihood, Peri-Urban, Urban Expansion, Vulnerability, Bahir Dar-Ethiopia.

5.1. Introduction

The 21st century is defined by the convergence of two global megatrends; rapid urbanization and accelerating climate variability. Together, these forces are fundamentally reshaping socio-ecological systems and human livelihoods worldwide (Almulhim et al., 2022; Li et al., 2020). While urbanization can be a driver of economic growth, its rapid pace in developing nations presents profound challenges, particularly for populations reliant on natural resources (Squires & Gaur, 2020). Projections indicate that nearly three forth of the world's population will be urban by 2050, with the most intense growth occurring in Africa and Asia (Dodman et al., 2022; Menashe and Bocquier, 2021; UNECA, 2022). Africa's urban population alone is set to double by 2050, adding approximately 950 million people to its cities (UNECA, 2018; Berry, 2008; Brenner, 2013).

Ethiopia stands as a prominent example of this rapid transformation, with one of the highest urbanization rates on the continent, estimated at 4.1% annually (CSA, 2018). The nation's urban population has surged from 9.1% in the 1970s to a projected 31% by 2037 (CSA, 2013; World Data Atlas, 2022). This expansion primarily occurs at the peri-urban interface, a dynamic zone where urban and rural systems collide. Here, urban growth often consumes prime agricultural land, leading to significant Land Use and Land Cover (LULC) changes and disrupting local ecosystems (Kindu et al., 2020; Seto et al., 2012).

Concurrently, climate variability driven by both anthropogenic and natural factors aggravates these pressures. The global mean surface temperature has already risen by approximately 0.6°C and is projected to increase by a further 1.4°C to 5.8°C by 2100 (IPCC, 2022). In Ethiopia, these warming trends are coupled with high spatial and temporal rainfall variability, heightening the risk of extreme weather events like droughts and floods (Alizadeh, 2023; Almazroui et al., 2020). Projections for Ethiopia indicate significant temperature increases and unpredictable precipitation shifts under all emission scenarios, threatening the rain-fed agricultural systems upon which a majority of the population depends (Birara et al., 2020; Getachew and Manjunatha, 2021; Kuma et al., 2022).

While urbanization can bring significant benefits, including improved access to markets, infrastructure, and non-farm employment, its rapid and often unplanned nature creates a unique and acute set of challenges for peri-urban farmers. The dual pressure of urban expansion and climate variability places these communities at the frontline of profound environmental change. Recent projections show that by 2030, global urban expansion could consume 1.8 to 2.4% of the world's croplands, a loss that disproportionately affects highly productive agricultural areas in Africa and Asia (D'Amour et al., 2017). This land conversion forces farmers onto smaller,

more fragmented plots while they must simultaneously contend with climate-induced risks. The IPCC highlights that climate change has already reduced agricultural productivity growth across Africa by 34% since 1961, a trend that is projected to accelerate IPCC (2022) . This transformation of their environment often forces them into more unstable livelihoods, increasing their vulnerability. As defined by the IPCC, vulnerability is the predisposition to be adversely affected, which encompasses sensitivity to harm and a lack of capacity to cope and adapt. Assessing this vulnerability in the complex peri-urban context is therefore critical for designing effective and sustainable development strategies.

Bahir Dar, the capital of the Amhara National Regional State (ANRS), serves as a typical example of these converging challenges. Since its designation as the regional seat of government in 1994, the city has been transformed by specific political and socio-economic dynamics, including its role as a strategic administrative hub and a center for horticulture and tourism within the UNESCO Lake Tana Biosphere Reserve. This administrative status has catalyzed exponential spatial growth, expanding the urban footprint into adjacent agricultural lands and vital wetland ecosystems (Aboye et al., 2023; Admasu et al., 2020; Melese et al., 2025). The city's expansion is not merely a demographic phenomenon but a product of state-led spatial-administrative transformations, where the implementation of the City Structural Plan involves the expropriation of peri-urban land. Consequently, these farmers face land fragmentation, resource competition, and socio-economic displacement (Idris et al., 2020; Kassahun, 2018; Gebeyehu et al., 2022). With the population projected to triple by 2035, the pressure on peri-urban farmers and their land-based livelihoods governed by complex state-ownership tenure will only intensify.

International studies have explored the impacts of urbanization on farmers in China (Huang et al., 2017) or climate vulnerability in urban slums in India (Pandey et al., 2018) or climate change vulnerability on urban households in Vietnam (Ngu et al., 2023). However, these studies do not address the specific context of peri-urban farmers in a developing country like Ethiopia, where land tenure is uniquely characterized by state ownership. Ethiopian farmers hold only usufruct (use) rights, making them legally and economically susceptible to state-led land expropriation for urban expansion, often accompanied by inadequate or delayed compensation (Talema & Nigusie, 2023). This structural tenure insecurity, combined with ambiguous institutional boundaries between 'urban' and 'rural' administrations, creates a distinct vulnerability context.

A significant body of research in Ethiopia has examined livelihood vulnerability to climate variability (Alemayehu et al., 2023; Bitana et al., 2023; Mekonen and Berlie, 2021; Yimam

and Holvoet, 2023). While these studies offer crucial insights, they operate under a dominant conceptual viewpoint that treats vulnerability as a rural, agrarian problem driven almost exclusively by hydro-meteorological shocks. This study actively argues against this climate-only perspective, revealing a critical conceptual and methodological gap. Conceptually, standard environmental frameworks treat urban expansion and climate change as separate, parallel pathways, thereby neglecting how state-led anthropogenic land transformations directly alter and compound climate sensitivity. Methodologically, existing indices in Ethiopia have been calibrated almost exclusively for rural settings, failing to account for the interconnectedness of climatic and spatial-administrative disturbances. This study offers a methodological advancement to the traditional vulnerability framework. It adapts the Hahn et al. (2009) LVI tool to formally integrate quantitative indicators of urban encroachment and tenure insecurity alongside climate metrics. Assessing this compounded vulnerability in the complex peri-urban context is therefore critical for designing effective, cross-sectoral development strategies.

By challenging the conventional separation of climatic and non-climatic stressors, this study fills this conceptual and methodological gap by providing a targeted assessment of vulnerability that treats the peri-urban interface not as a rural extension, but as a distinct socio-spatial zone defined by its own stressors. Specifically, we argue against the practice of evaluating climate vulnerability without accounting for active, urban-driven resource depletion. this study explicitly integrates these dimensions by operationalizing urban expansion through specific quantitative metrics of land expropriation, tenure insecurity, and market-driven shifts in natural capital. By adopting a mixed-methods approach grounded in the IPCC framework, this study clarifies the distinct and compounded effects of these stressors. Therefore, the main objective of this study is to analyze the extent and nature of livelihood vulnerability among peri-urban farmers in Bahir Dar to the combined effects of urban expansion and climate variability. By doing so, the study aims to identify its key determining factors and generate policy-relevant insights for enhancing community resilience and promoting sustainable development.

5.2. Methods and materials

5.2.1. Description of the study area

The study was conducted in the peri-urban areas of Bahir Dar, the capital city of the ANRS, Ethiopia. Geographically, the city is situated between 11° 25' 11" to 11° 58' 11" N latitude and 37° 2' 2" to 37° 42' 4" E longitude, approximately 567 km northwest of Addis Ababa

(Asmamaw and Debie, 2023). The landscape is predominantly flat, with elevations ranging from 1,708 to 2,007 meters, a characteristic that has facilitated rapid horizontal urban expansion into adjacent lands. This study focuses specifically on the peri-urban administrative kebeles including Zenzelma, Woreb Kola, Sebatamit, Addis Alem, Yibab, and Woramit which form a transitional zone between the core urban sub-cities and the surrounding rural landscape.

To clearly communicate the relevance of this location to the study's core objectives, Figure 5.1 presents a 40-year Land Use/Land Cover (LULC) time-series rather than a standard static location map. The primary message this map is intended to convey is the aggressive outward expansion of the built-up urban core (red) into surrounding agricultural lands. By overlaying the boundaries of the study kebeles, the map explicitly demonstrates the spatial exposure and encroachment pathways directly impacting the surveyed farmers, thus providing physical evidence for the 'urban expansion' stressor analyzed in the LVI framework.

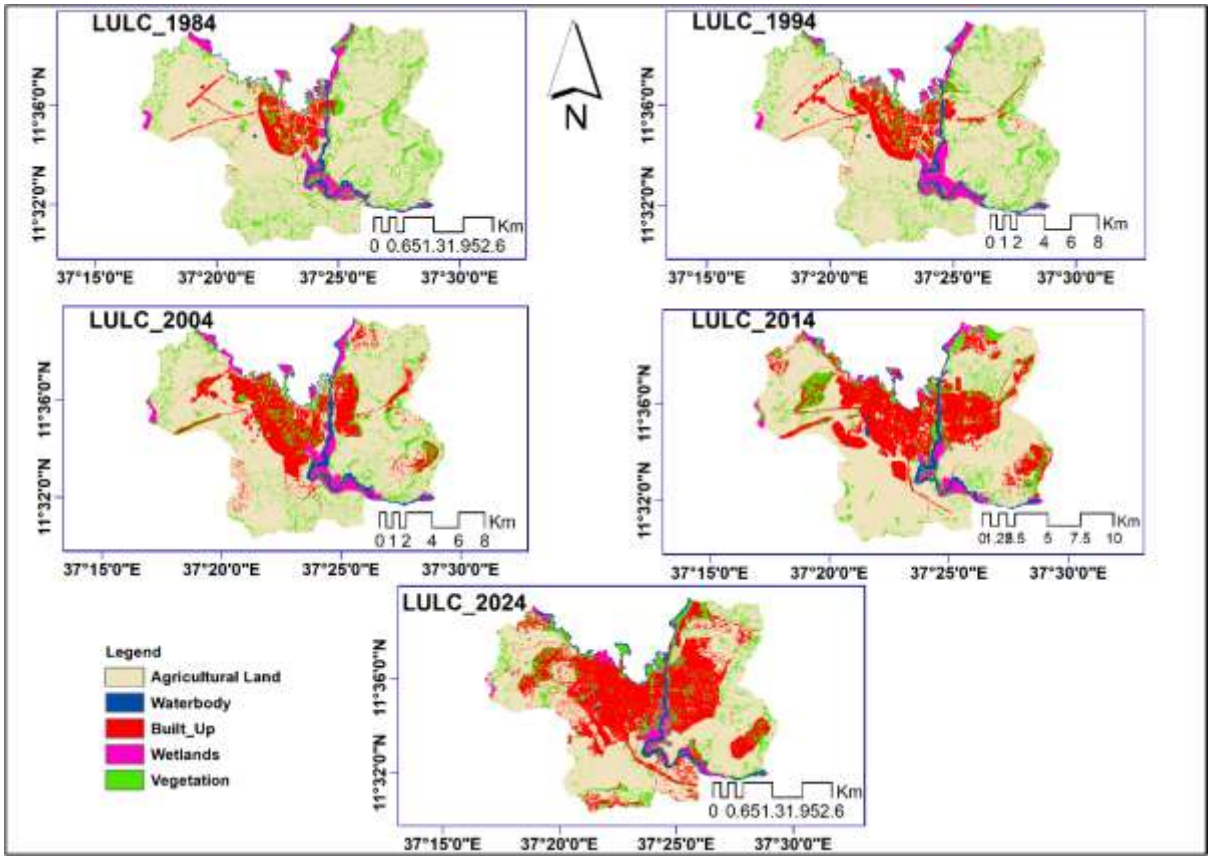


Figure 5.1 Spatial dynamics of urban expansion in the study area (1984-2024)

This map serves a dual purpose; it locates the four surveyed peri-urban kebeles (outlined in black) and visually quantifies the historical trajectory of the built-up area (red), demonstrating the direct spatial exposure of these farming communities to land encroachment.

The city's historical trajectory is central to understanding the current pressures on peri-urban livelihoods. While its origins are ancient, its modern transformation began when it was

designated the regional capital in 1994 (Haregeweyn et al., 2012). This administrative shift acted as a catalyst for accelerated urbanization, attracting significant public and private investment and fueling rapid rural-to-urban migration. Consequently, Bahir Dar's population grew exponentially, from 96,140 in 1994 (CSA, 1995) to an estimated 500,000 by 2020 (Bahir Dar City Structural Plan Preparation Project Office, 2020). This demographic and economic dynamism has driven the city's physical expansion, leading to widespread conversion of agricultural land, forests, and wetlands in the peri-urban fringe to accommodate new residential and commercial developments.

The economy of the core urban area is diverse, including manufacturing, services, and a prominent tourism sector (UNESCO, 2015). However, the livelihoods in the study's focal peri-urban kebeles remain predominantly agricultural, based on the cultivation of crops, horticulture, and livestock rearing. These communities are therefore directly exposed to the impacts of land-use changes driven by the city's growth.

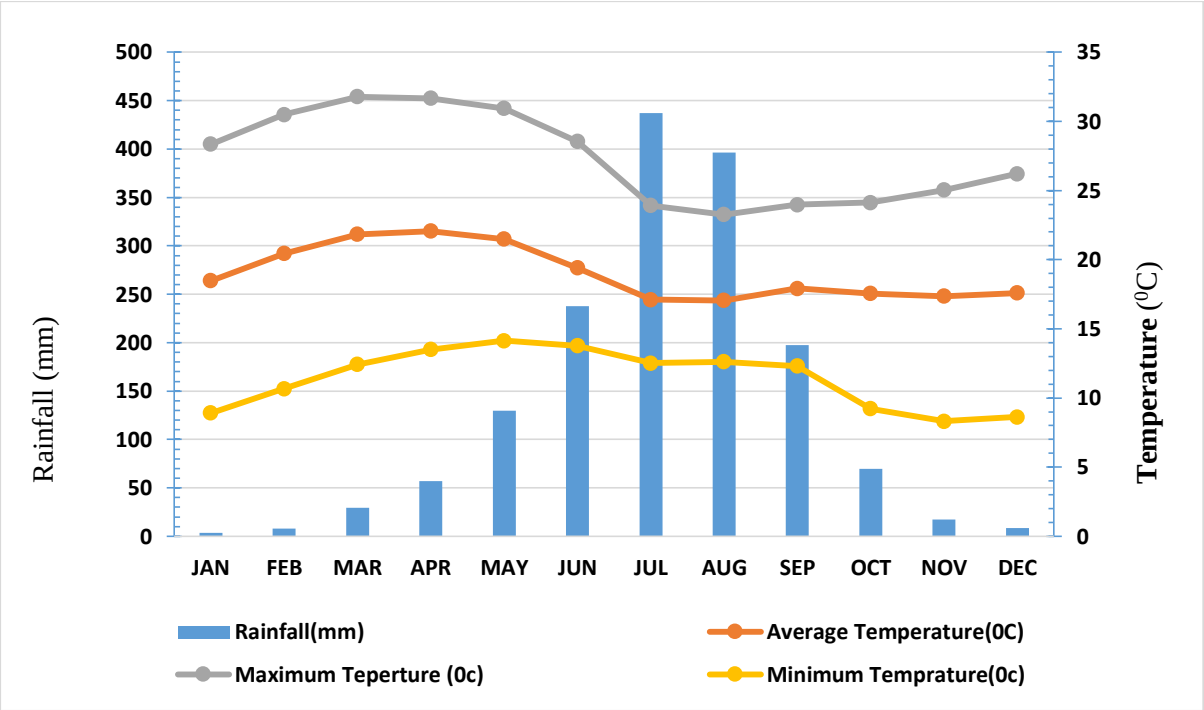


Figure 5.2 Mean Monthly Rainfall and Temperatures of Bahir Dar from 1984 – 2022

The study area is located within the Woina Dega (tropical savannah) agro-ecological zone, characterized by a monomodal rainfall pattern. The primary rainy season occurs from June to August, with annual precipitation totals averaging around 1446 mm, while the period from December to February is typically dry (Figure 5.2). Long-term climatic data (1984-2022) reveal two significant trends to this study; (1) a consistent increase in both mean minimum and

maximum temperatures, indicating a clear warming trend, and (2) high inter-annual and seasonal variability in rainfall. These climatic shifts, particularly the unpredictability of rainfall, pose a significant and growing threat to the rain-dependent agricultural livelihoods of the peri-urban farmers, compounding the pressures they already face from urban expansion.

5.2.2. Research design and methodology

This study employed a convergent parallel mixed-methods design to conduct a comprehensive assessment of livelihood vulnerability among peri-urban farmers in Bahir Dar. This approach was selected for its ability to provide a more robust and nuanced understanding of the research problem than a single method could alone (Creswell, 2009). The core of this design involves the simultaneous collection and analysis of quantitative and qualitative data. The quantitative data, derived primarily from a household survey, was used to construct a LVI and measure the extent of vulnerability. Concurrently, qualitative data from FGDs were used to explore the context, lived experiences, and underlying drivers of this vulnerability. The final stage involves integrating these two data streams to triangulate findings and generate more holistic, evidence-based conclusions (Doyle et al., 2016; Poth, 2018).

5.2.3. Data Sources and Collection Tools

The data collection process for this study encompass a diverse array of primary and secondary data sources. These sources exhibited both quantitative and qualitative attributes.

5.2.3.1. Primary Data Collection

i. Household Survey

The primary quantitative data was collected through a household survey administered via structured interviews. This interviewer-led approach was chosen to ensure clarity and a high response rate among respondents with varying literacy levels. The survey instrument (provided in Supplementary Material) was structured into distinct sections to capture the multidimensional nature of vulnerability. The questionnaire measured specific livelihood capitals through targeted modules (Social Networks, Livelihood Strategies, Socio-demographic Profile, Food Security, LULC Sustainability, Water Access, Infrastructure, Climate Variability/Hazards, and Technology Access). The tool was developed based on the LVI framework, adapted for the local context through consultation with development agents, and pilot-tested with 15 households in a non-sampled kebele.

ii. Focus Group Discussions

Qualitative data was gathered through FGDs to add explanatory depth to the quantitative findings. A semi-structured checklist (provided in Supplementary Material) guided these discussions across six core analytical themes; 1) Perceptions of Climate Variability, 2) Urban Expansion and Land Use Change, 3) Livelihood Impacts, 4) Coping/Adaptation Strategies, 5) Access to Support/Technology, and 6) Institutional/Governance Issues. Qualitative insights from these FGDs played a dual methodological role. First, during the study's design phase, informal community consultations informed the selection of locally relevant indicators (e.g., explicitly adding "loss of farmland" to capture land expropriation). Second, during the analysis phase, the qualitative themes were used to interpret, validate, and provide lived context to the quantitative index scores.

5.2.3.2. Secondary Data Collection

iii. Climatic Data

Long-term climatic data for peri-urban areas of Bahir Dar, including monthly temperature and rainfall records from 1994 to 2022 were obtained from the National Meteorological Agency (NMA). This historical data was essential for objectively quantifying the exposure component of the vulnerability framework by analyzing climatic trends and anomalies.

iv. Document Review

A thorough review of secondary documents was conducted to understand the broader policy and institutional context. This included national and regional urban development plans, climate change adaptation strategies, official government reports, academic literature, and previous studies on land use and livelihoods.

5.2.4. Sampling Design and Procedure

This study employed a multistage sampling procedure to select the household respondents for the quantitative survey. The selection of qualitative participants for FGDs was done purposively.

5.2.4.1. Selection of the Study Area and Kebeles

Stage One: The city of Bahir Dar was purposively selected as the study area. This selection was based on its documented status as a center of rapid urban expansion, significant land use transformation, and increasing vulnerability to climate-related challenges, making it an ideal case for this study (Adigeh & Abebe, 2023; Digafe et al., 2024; Getu & Bhat, 2024).

Stage Two: From the six peri-urban kebeles, four were purposively selected (Addis Alem, Zenzelma, Woreb Kola, and Woramit) based on their distinct vulnerability profiles and exposure to specific urban expansion corridors. Addis Alem was selected due to its location at the immediate urban fringe, experiencing the highest rates of residential land expropriation. Woreb Kola is situated along the primary urban expansion axis, where industrial development and road infrastructure are most aggressive. Zenzelma represents an expansion corridor toward major institutional developments (university), while Woramit was chosen to capture the vulnerability of high-value horticultural lands near the lake and river that are increasingly encroached upon by tourism and recreational construction. These kebeles collectively represent a vulnerability gradient, making them ideal for analyzing the diverse impacts of the city's spatial-administrative transformation.

5.2.4.2. Selection of Households and Sample Size

Stage Three: Within the four selected kebeles, individual farming households were selected using systematic random sampling. First, a comprehensive list of all farming households was obtained from the respective kebele administrative offices to serve as the sampling frame. The total number of households (N) in this frame was 24,412, projected from Bahir Dar City Structural Plan Preparation Project Office Report (2020).

The sample size (n) was calculated using the Kothari (2004) formula for a finite population (Equation 17).

$$n = \frac{Z^2 \times p \times q \times N}{e^2(N-1) + Z^2 \times p \times q} \qquad (17)$$

Where,

n = required sample size

Z = confidence level at 95%, Z ≈ 1.96

P = sample proportion = 35% (Geleta, 2023)

q = 1-P

N= total number of households = 24,412

E = desired margin of error = 5%

Based on this calculation, the required sample size was determined to be 345 households. To select the households, a sampling interval (k) was calculated by dividing the total number of households (N) by the sample size (n). A random starting point between 1 and k was chosen, and every k^{th} household was selected from the list until the target of 345 households was

achieved. This systematic approach ensures that the sample is spread across the entire population list while maintaining the principles of random selection.

5.2.4.3. Selection of FGD Participants

Participants for the FGDs were selected purposively to ensure a diversity of information-rich perspectives across age, role, and gender. One FGD was conducted in each of the four sampled kebeles. Each group comprised six members with a deliberate inclusion of both women and men i.e. two elderly farmers (selected for their long-term residency and deep knowledge of historical changes), one kebele administrator, two community representatives, and one agricultural development agent (selected for their institutional and technical expertise). This composition was designed to capture a range of experiences including potentially gender-differentiated ones with the impacts of urban expansion and climate variability, ensuring the qualitative data would effectively complement the quantitative findings.

5.2.5. Methods of Data Analysis

5.2.5.1. Quantitative Data Analysis

While several indices exist to measure livelihood vulnerability, this study required a framework capable of assessing the impacts of both climate variability and urban expansion. The LVI, developed by Hahn et al. (2009), was selected for this purpose. The primary rationale for choosing the LVI is its flexibility, which allows for the integration of diverse indicators including both climate and non-climate stressors, within the IPCC's vulnerability framework of exposure, sensitivity, and adaptive capacity. This adaptability makes it particularly well-suited for analyzing the complex, multi-stressor environment of a peri-urban interface.

The selection of specific indicators for this study was a multi-step process designed to capture the unique pressures faced by farmers in Bahir Dar. An initial pool of indicators was drawn from an extensive review of literature focused on livelihood vulnerability to climate stressors in Ethiopia (Alemayehu, 2023; Amare, 2018; Lewte, 2019; Melesse, 2023; Nigani, 2020; Shiferaw, 2018), which highlighted key factors like rainfall variability, food and water security, and socio-demographic profiles. However, because these studies often overlook the crucial impact of non-climate, urban-related stressors, this initial list was expanded and customized.

Drawing on peri-urban literature and consultations with local development agents, specific indicators were incorporated to explicitly measure the impacts of urban expansion. Crucially,

to operationalize the vulnerability arising from Ethiopia's unique state-owned land tenure system and the constant threat of expropriation, we included urban expansion-related variables such as "loss of farmland" and "conversion of agricultural to non-agricultural land." These act as direct, measurable proxies for tenure insecurity and displacement at the peri-urban fringe. This customized approach ensures that the final index provides a holistic and contextually relevant assessment of livelihood vulnerability to the dual pressures that define the peri-urban experience in Bahir Dar.

To maintain analytical clarity and address the complex intersection of dual stressors, this study explicitly delineates the boundaries between exposure, sensitivity, and adaptive capacity. Following the foundational methodology of Hahn et al. (2009), this framework deliberately integrates the Sustainable Livelihoods Approach (SLA); represented by the five livelihood capitals; with the IPCC vulnerability dimensions. Rather than creating conceptual overlap, this integration provides a structured matrix where specific livelihood assets mathematically map onto broader IPCC dimensions.

To avoid circular reasoning; where vulnerability outcomes are conflated with vulnerability drivers; indicators categorized under Sensitivity and Adaptive Capacity were strictly operationalized as pre-existing baseline conditions rather than post-shock outcomes. Exposure is operationalized as the physical manifestation of exogenous hydro-meteorological hazards (e.g., rainfall variability, flood frequency).

Sensitivity represents the inherent, baseline precariousness of the household's livelihood system. For instance, indicators such as "months households struggle to find food" or "loss of farmland" do not measure the outcome of a specific recent shock; rather, they capture the fragile baseline state of the household's food and natural capital systems. This underlying fragility dictates how severely the household will be affected by ongoing or future exposures. Adaptive Capacity is strictly bounded to represent the latent asset base (e.g., human, social, physical, and financial capitals) that households can mobilize to buffer against these ongoing sensitivities and exposures.

Furthermore, to address potential conceptual overlap among indicators (e.g., 'dependence on agriculture' versus 'dependence on family farming for food'), indicators were strictly delineated by their functional role in the livelihood system. For instance, 'dependence on agriculture' was operationalized as a measure of economic and income diversification (Adaptive Capacity), whereas 'dependence on family farming for food' measured subsistence caloric reliance

(Sensitivity). Because households may cultivate cash crops without consuming them, or rely on remittances while farming for subsistence, these represent distinct vulnerability pathways. Mathematically, the risk of double-counting inflating the index is mitigated by the LVI's hierarchical averaging structure (Equation 3 and 4), where sub-indicators are first averaged into distinct major components before being aggregated into the final index.

Table 5.1 Major components and sub-components for the LVI analysis

Vulnerability factors	Livelihood Capitals	Major Indicator	Sub-Indicator	Hypothesized Assumption	Sources
Exposure	Natural Capital	Climate variability& hazards	Change in max temperature	Higher climate variability increases exposure and livelihood vulnerability	(Alemayehu, 2023; Amare, 2018; Hahn et al., 2009; Lewte, 2019; Nigani, 2020; Ofgeha, 2021; Shiferaw, 2018)
			Change in min temperature		
			Change in precipitation		
			Frequency of drought events		
			Frequency of Flood risk		
Sensitivity		Land use & sustainability	Farm size	Loss of farmland and poor conservation raise sensitivity to shocks	(Ofgeha, 2021; Seto et al., 2011; Shiferaw, 2018)
			Conversion of agricultural to non-agricultural land		
			Loss of farmland		
			soil conservation practice		
			Water conservation practice		
		Water	Availability of potable water	Limited water access increases sensitivity and reduces production	(Alemayehu, 2023; Amare, 2018; Hahn et al., 2009; Nigani, 2020)
			Access to potable water		
			Conflict over water in		
	Financial Capital	Food	Total production/year (inverse)	Seasonal shortages and low crop diversity heighten sensitivity	(FAO, 2013; Hahn et al., 2009; Nigani, 2020; Shiferaw, 2018)
			HHs dependent on family farm for food		
			Months HHs struggle to find food		
			Diversity of crops grown		
Adaptive capacity		Livelihood strategies	Diversification of income sources	Low livelihood diversification reduces adaptive capacity	(Amare, 2018; Ellis, 2000; Hahn et al., 2009; Shiferaw, 2018)
			Dependence on agriculture		
			income from off-farm sources		
			income from non-farm sources		
	Physical capital	Infrastructure	Access to all-weather roads	Poor infrastructure access lowers adaptive capacity	(Alemayehu, 2023; Lewte, 2019; Shiferaw, 2018)
			Access to health service		
			Access to veterinary service		
			Access to school		
			Access to market		
			Access to savings & credit services		
			Access to electricity		
		Technology	Pesticide and insecticide supply	Limited inputs and climate information weaken adaptive capacity	(Alemayehu, 2023; Amare, 2018; Melesse, 2023; Shiferaw, 2018)
			Availability of fertilizer		
			Availability of improved seed		
			Access to climate information		
	Human capital	Socio-demographic profile	Dependency ratio	High dependency ratios and low education reduce adaptive capacity	(Alemayehu, 2023; Cutter et al., 2003; Hahn et al., 2009; Lewte, 2019; Nigani, 2020)
			HH gender ratio		
			HH head's educational status		
			Farming experience		
			Access to extension service		
	Social capital		Membership in community based organizations (CBO)	Weak social networks limit adaptive capacity in crises	(Adger, 2003; Alemayehu, 2023; Amare, 2018; Lewte, 2019)
			The practice of working together		
			Access to support during crises		

		Social networks	Number of non-working days/month		
			Access to credit services		

Despite variations in the number and categorization of indicators across studies, a synthesis revealed recurring themes. Depending on the literature above common indicators utilized for this study include social networks; livelihood strategies; socio-demographic profile; food; LULC change and sustainability; water; infrastructure; climate variability and hazards; and technology. These indicators collectively capture the complex interplay of socio-economic, environmental, and institutional factors shaping livelihood vulnerability. Such a comprehensive understanding is essential for designing effective interventions and policies to enhance community resilience and reduce vulnerability to external shocks and stresses. Furthermore, the sub-components within the major components of the vulnerability were customized to the local context in consultation with loacl development agents (Table 5.1).

To calculate the LVI, researchers used a balanced weighted average approach where each subcomponent contributes equally to the overall index through each major component which comprised different number of sub-components. No prior assumption will be made about the importance of each indicator or main component in the overall sum. This assessment tool will be accessible to a diverse set of users in resource-poor settings. Minimum and maximum values will be used to transform indicators into a standardized index.

To operationalize the LVI framework, raw survey responses were systematically transformed into measurable continuous variables or percentages before standardization. For continuous data (e.g., household size, walking hours to a market, total farm size), the raw values were averaged at the kebele level. For binary or categorical responses (e.g., answering "Yes" or "No" to having access to electricity or early warning systems), the data were aggregated as the percentage of households reporting the specific condition within each kebele. These aggregated raw values for each kebele were subsequently standardized to allow for cross-indicator comparison.

The standardized value for the indicator denoted as LVI, was calculated using Equation 18.

$$LVI = \frac{Sa - Smin}{Smax - Smin} \quad (18)$$

Where,

Sa represents the observed (average) sub-component indicator for *kebele* a,

Smax and Smin represent the minimum and maximum values, respectively, for the indicator across the different *kebeles*.

Next, the sub-component indicators were averaged to calculate the index for each principal component (Equation 19).

$$M_a = \frac{\sum lvi}{N} \quad (19)$$

Where,

M_a represents one of the 9 major components for sample *kebele* a.

lvi represents the sub-components indexed by i,

"N" signifies the number of sub-components in each major component.

Then, the weighted averages of all the major components were combined to generate the LVI score using Equation 20.

$$LVI_a = \frac{\sum_{p=1}^{9} WM_i M_{ai}}{\sum_{p=1}^{9} WM_{ai}} \quad (20)$$

Where,

LVIa, is the LVI Index for *kebele* a.

WM_i, is number of indicators used to determine the weights of each major component.

Values for each of the 9 major components for sample *kebeles* were calculated and averaged to obtain the *kebele*-level LVI. By employing the three equations mentioned above, the primary components of LVI were calculated based on the LVI-IPCC vulnerability classification into Exposure (E), Sensitivity (S), and Adaptive capacity (A), as outlined in Equation 21.

$$CF_a = \frac{\sum_{p=1}^{f} WM_i M_{ai}}{\sum_{p=1}^{f} WM_{ai}} \quad (21)$$

Where,

CF_a denotes the contributing factors defined by LVI-IPCC for the sample kebele a,

M_{ai} refers to the major components indexed by i for sample kebele a,

WM_i represents the weights assigned to each major component,

f indicates the number of profiles related to the contributing factors,

p is indexed to the profiles linked with the CF.

Ultimately, the LVI-IPCC was calculated using Equation 22.

$$LVI_IPCC_a = (E_a - A_a) \times S_a \quad (22)$$

Where,

LVI-IPCCa represents the Livelihood Vulnerability Index for sample kebele a,

E_a denotes the computed exposure score for sample kebele a,

A_a signifies the computed adaptive capacity score for sample kebele a, and

S_a represents the computed sensitivity score for sample kebele a.

The LVI-IPCC was standardized on a scale from -1 (indicating the least vulnerable) to 1 (indicating the most vulnerable), providing an estimation of relative vulnerability. To aid in interpretation and comparison, the final LVI-IPCC scores were classified into three vulnerability levels based on an equal-interval scale, a common approach in vulnerability literature (Namgyal et al., 2025; Suryanto & Rahman, 2019). The resulting classification defined scores from -1.000 to -0.334 as least vulnerable, from -0.333 to 0.333 as moderately vulnerable, and from 0.334 to 1.000 as highly vulnerable.

The equal-interval approach was deliberately chosen to provide an objective, mathematically symmetrical partitioning of the index range, avoiding subjective bias in threshold setting (Hahn et al., 2009). Conceptually, the 'Moderately Vulnerable' central interval (-0.333 to 0.333) captures communities residing near the mathematical zero-threshold, where adaptive capacity and exposure are nearly equal. Classifying slight negative scores within this moderate band is theoretically critical; it reflects that while adaptive capacity may marginally exceed exposure, the margin of safety is razor-thin and heavily mediated by the system's underlying sensitivity.

Following the LVI methodology proposed by Hahn et al. (2009), this study employed a balanced weighted average approach where each of the major components contributes equally to the overall index. While alternative weighting methods, such as Principal Component Analysis or entropy weighting, are highly valuable and widely utilized for data reduction in vulnerability assessments, this specific study deliberately retained the equal-weighting approach for three critical reasons. First, from a Sustainable Livelihoods Framework perspective, equal weighting treats all foundational components of survival (e.g., water, food, social networks) as inherently essential, avoiding assumptions regarding which asset is 'more important' for basic resilience.

Second, utilizing the standard equal-weighting approach maintains the structural integrity of the original Hahn et al. (2009) framework, ensuring that the findings from Bahir Dar can be directly compared with a broad baseline of standard LVI studies globally. Finally, equal

weighting maximizes computational transparency, making the tool highly accessible and actionable for local urban planners who must deconstruct these indices to design targeted interventions.

Furthermore, comparative studies in vulnerability assessments frequently demonstrate that equal and statistically derived weighting schemes yield highly correlated spatial rankings, confirming the robustness of the equal-weighting approach for this context (Moreira et al., 2023; Panthi et al., 2015). Importantly, the methodological novelty of this study resides in the innovative synthesis of urban-encroachment and climate-risk indicators within a unified index, rather than the statistical weighting itself. Retaining the equal-weighting approach ensures that the results remain transparent and deconstructable for local planners, which is the primary objective of this assessment.

5.2.5.2. Data Reliability and Validity

The validity of the LVI components and sub-indicators was established through a comprehensive review of existing literature and expert consultation with local development agents, ensuring their relevance to the study context. Furthermore, the internal consistency and reliability of the sub-indicators grouped under each major LVI component were statistically tested using Cronbach's Alpha. This test measures the extent to which the sub-indicators for each component consistently measure the same underlying construct. A Cronbach's Alpha coefficient of 0.70 or higher is considered acceptable for demonstrating reliability (Hussey et al., 2025).

5.2.5.3. Qualitative Data Analysis and Integration with Quantitative Findings

To ensure qualitative rigor and move beyond the use of FGDs as mere illustrative quotations, the qualitative data were systematically processed using reflexive thematic analysis (Braun & Clarke, 2006). The analytical procedure followed a rigorous framework: 1) familiarization with the data through repeated reading of translated transcripts and field notes; 2) manual generation of initial codes; 3) searching for overarching themes; 4) reviewing themes; 5) defining and naming themes; and 6) integrating the analysis. The coding framework utilized a hybrid approach. Deductive codes were generated a priori based on the major components of the LVI (e.g., 'climate hazards', 'infrastructure deficits', 'social networks') to allow for direct triangulation with the quantitative data. Simultaneously, inductive codes were allowed to emerge organically from the participants' narratives to capture unquantified local realities (e.g., 'institutional mistrust', 'generational knowledge gaps', 'tenure anxiety'). Rather than simply

quoting participants, these synthesized themes were analytically integrated with the quantitative index to explain the causal mechanisms, structural constraints, and human behaviors that drive the numerical vulnerability scores.

A mixed-methods triangulation approach was used to merge qualitative themes with quantitative results at the kebele and indicator levels during the interpretation phase. Crucially, qualitative insights from the FGDs did not alter or influence the mathematical scoring of the LVI indicators. Instead, the integration served an explanatory and contextualizing function. For instance, in assessing 'Exposure', meteorological time-series data provided the objective quantitative score, while FGD narratives were used solely to validate how these climatic trends were experienced on the ground (e.g., the timing and localized impact of floods). This approach ensured methodological rigor by keeping the quantitative index mathematically independent, while utilizing qualitative data to explain the 'why' behind the numbers, thereby uncovering hidden dimensions of resilience and risk.

5.3. Results and Discussion

This section presents an integrated analysis of the LVI results, combining quantitative scores from the household survey with qualitative insights from FGDs. The discussion of each vulnerability component is supported by relevant literature to contextualize the findings. To first establish the robustness of the quantitative findings, a reliability analysis was performed on the major LVI components. As shown in Table 5.2, all nine components demonstrated acceptable to high internal consistency, with Cronbach's Alpha coefficients ranging from 0.71 to 0.89. This confirms that the sub-indicators used are reliable measures of their respective underlying constructs. The detailed LVI scores, which form the basis of the subsequent analysis, are presented in Table 5.3.

Table 5.2 Cronbach's Alpha Reliability Coefficients for LVI Major Components

Major Component	Number of Sub-Indicators	Cronbach's Alpha (α)	Interpretation (Babbie, 2013)
Climate variability & hazards	5	0.79	Acceptable reliability
Land use & sustainability	4	0.81	High reliability
Water	3	0.75	Acceptable reliability
Food	4	0.85	High reliability
Livelihood strategies	4	0.72	Acceptable reliability
Infrastructure	6	0.89	High reliability
Technology	4	0.71	Acceptable reliability
Socio-demographic profile	5	0.80	High reliability
Social networks	5	0.83	High reliability

Table 5.3 LVI Scores for Major Components and Sub-Indicators across Kebeles

Factors	Capitals	Major Indicators	Sub-Indicator	Units	Indexed value				
					Addis alem	Zenzelma	Woreb Kola	Woramit	**Average**
Exposure	Natural Capital	Climate variability & hazards	Change in max temperature	SD of monthly average max. temperature (1984-2022)	0.61	0.47	0.52	0.56	.540
			Change in min temperature	SD of monthly average min. temperature (1984-2022)	0.41	0.37	0.46	0.33	.393
			Change in precipitation	SD of monthly average rainfall (1984 - 2022)	0.82	0.67	0.79	0.64	.730
			Frequency of drought events	Number of events over the last 20 years	0.25	0.18	0.29	0.16	.220
			Frequency of Flood risk	Number of events over the last 20 years	0.59	0.42	0.5	0.46	.493
			Weighted Average Score		**.536**	**.422**	**.512**	**.430**	**.475**
Sensitivity		Land use & sustainability	Farm size	Ha/HH	0.6	0.49	0.62	0.5	.553
			Conversion of agricultural to non-agricultural land	Land conversions/hec	0.52	0.4	0.49	0.46	.468
			Loss of farmland	Land lost/hec	0.46	0.35	0.44	0.34	.398
			Soil and water conservation practice	Average hectare of land under SWC	0.62	0.5	0.59	0.53	.560
			Weighted Average Score		**.550**	**.435**	**.535**	**.458**	**.495**
		Water	Availability of potable water	% of HHs access to consistent water supply	0.82	0.7	0.75	0.38	.663
			Access to potable water	Average time/min to a water source	0.54	0.63	0.59	0.68	.610
			Conflict over water	% of HHs facing the problem	0.58	0.46	0.55	0.53	.530
			Weighted Average Score		**.647**	**.597**	**.630**	**.530**	**.601**
	Financial Capital	Food	Total production/year (inverse)	Total production/HH/year	0.81	0.7	0.82	0.76	.773
			HHs dependent on family farm for food	% of HHs dependent on family farm for food	0.96	0.91	0.95	0.86	.920
			Months HHs struggle to find food	Average food insufficient months	0.39	0.34	0.41	0.32	.365
			Diversity of crops grown	Crop diversity index	0.63	0.56	0.61	0.55	.588
			Weighted Average Score		**.698**	**.628**	**.698**	**.623**	**.662**
Adaptive capacity		Livelihood strategies	Diversification of income sources	[1/ (no. of livelihood activities + 1)]	0.41	0.35	0.39	0.37	.380
			Dependence on agriculture	% of HHs agriculture as the main source of income	0.81	0.75	0.8	0.76	.780
			income from off-farm sources	Cash acquired per year	0.32	0.26	0.31	0.27	.290
			income from non-farm sources	Cash acquired per year	0.29	0.23	0.28	0.24	.260
			Weighted Average Score		**.458**	**.398**	**.445**	**.410**	**.428**
	Physical capital	Infrastructure	Access to all-weather roads	walking hours	0.57	0.49	0.54	0.53	.533
			Access to health service	walking hours	0.44	0.39	0.42	0.39	.410
			Access to veterinary service	walking hours	0.46	0.41	0.45	0.35	.418
			Access to school	walking hours	0.77	0.7	0.73	0.73	.733
			Access to market	walking hours	0.81	0.75	0.76	0.74	.765
			Access to electricity	% of HHs accessing electricity	0.15	0.13	0.16	0.11	.138
			Weighted Average Score		**.533**	**.478**	**.510**	**.475**	**.500**
		Technology	Pesticide and insecticide supply	%of HHs using pesticide & insecticide	0.49	0.4	0.46	0.44	.448
			Availability of fertilizer	%of HHs applying fertilizer	0.45	0.39	0.43	0.41	.420
			Availability of improved seed	%of HHs using improved seeds	0.7	0.61	0.68	0.65	.660
			Access to climate information	%of HHs having access to climate information	0.55	0.49	0.54	0.54	.530
			Weighted Average Score		**.548**	**.473**	**.528**	**.510**	**.515**
	Human capital	Socio-demographic profile	Dependency ratio	Dependency ratio	0.64	0.57	0.61	0.58	.600
			HH gender ratio	Gender ratio (Male/Female)	0.94	0.88	0.92	0.84	.895
			HH head's educational status	% of HH heads attending formal education	0.64	0.56	0.63	0.53	.590
			Farming experience	Average years of farming experience	.42	.38	.41	.39	.400
			Access to extension service	Number of DAs per kebele	0.71	0.61	0.67	0.63	.655

			Weighted Average Score		**0.67**	**0.6**	**.648**	**.594**	**.628**
	Social capital	Social networks	Membership in CBO	% of HHs who are members of CBO	0.77	0.72	0.76	0.8	.763
			The practice of working together	% of HH who have a tradition of working together	0.88	0.84	0.87	0.89	.870
			Access to support during crises	% of HHs received support	0.28	0.24	0.27	0.26	.263
			Number of non-working days/month	Average number of non-working days/month	0.44	0.39	0.46	0.42	.428
			Access to credit services	% of HHs borrowed money through social networks	0.45	0.42	0.48	0.44	.448
			Weighted Average Score		**.564**	**.522**	**.568**	**.562**	**.554**

Note: All LVI sub-indicators are standardized on a scale from 0.000 (indicating minimum vulnerability/highest capacity) to 1.000 (indicating maximum vulnerability/lowest capacity). For standard indicators (e.g., frequency of flood risk), higher values represent greater vulnerability. For inverse indicators (e.g., total production, soil and water conservation practices), the raw data were mathematically inverted during standardization so that higher index values systematically correspond to higher vulnerability or lower adaptive capacity, maintaining mathematical consistency across the index.

The vulnerability profiles across the nine major components (Figure 5.3) reveal that food and water insecurity are common drivers of vulnerability across all kebeles, while variations in physical capital and livelihood strategies differentiate the kebeles' overall resilience. This visual summary provides a diagnostic lens through which to examine the specific kebele-level performance in the following sections.

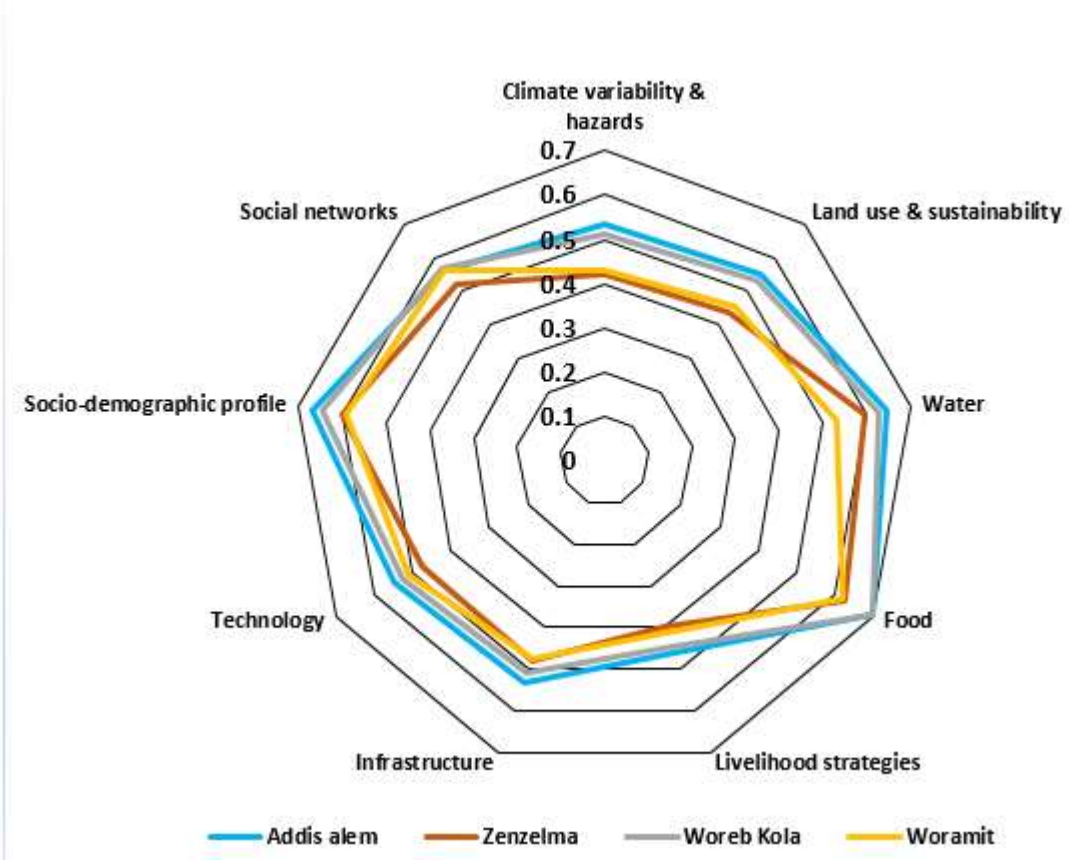


Figure 5.3 Livelihood vulnerability based on the nine major components of the LVI

5.3.1. Exposure to Climate Variability and Hazards

The analysis reveals that peri-urban households are subjected to significant climate-related exposure (average index = 0.475). While the four kebeles are part of the same local climate system and experience similar broad patterns of temperature and rainfall, the study found notable variations in exposure scores at the kebele level (Figure 5.4). Addis Alem (0.536) and Woreb Kola (0.512) registered the highest exposure. This variation is not attributed to different macro-climates, but rather to micro-level differences in topography and proximity to waterways, which result in a higher localized frequency of hazards like floods (average index = 0.493) (Figure 5.4). This is strongly corroborated by the FGDs, where farmers described highly localized events. For instance, a community representative recalled, "Two years ago, just before harvest, a flash flood washed away our sorghum and chickpea crops." This highlights how location-specific factors can create differential exposure even within the same area. However, while these localized exposure differences are important, the primary factors that determine the significant variation in overall livelihood vulnerability across the kebeles are their differential sensitivity and adaptive capacity, which are explored in the subsequent sections.

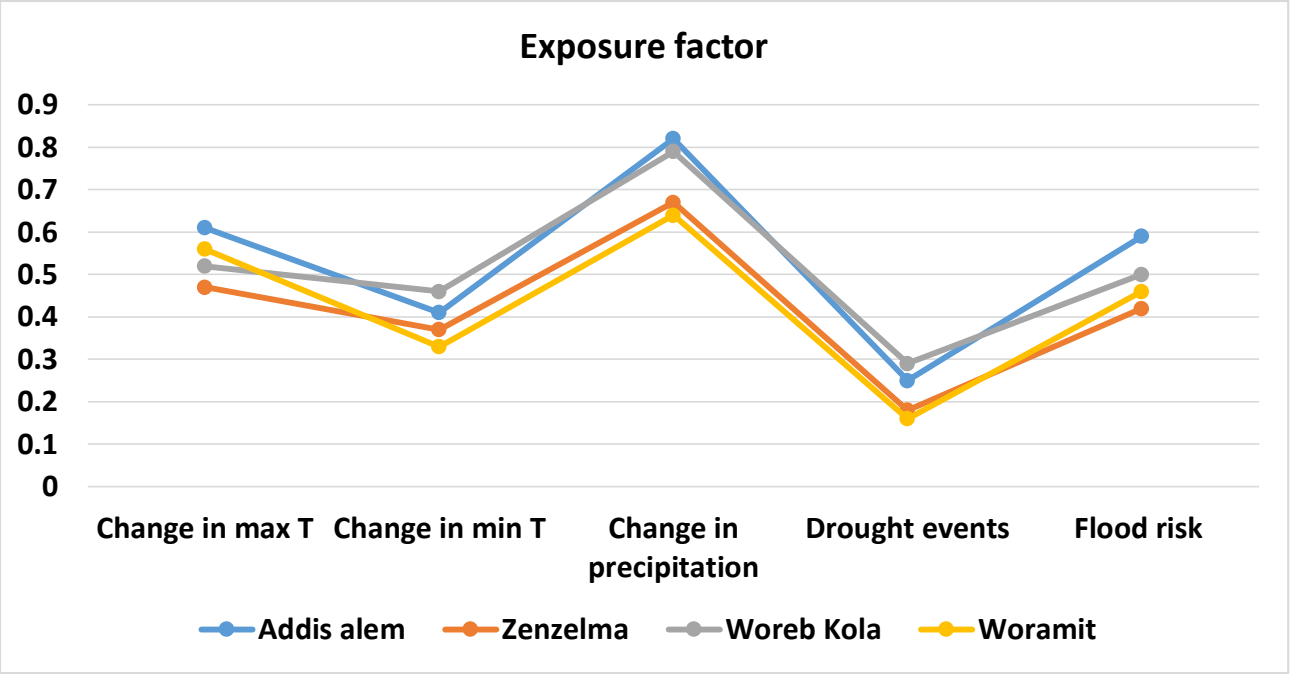


Figure 5.4 Indexed Scores for Exposure Sub-Indicators by Kebele

This quantitative finding is strongly supported by the lived experiences of the farmers. Participants across all FGDs reported that rainy seasons are no longer predictable,

fundamentally disrupting their agricultural practices. As an elderly farmer from Zenzelma expressed,

> In the past, the rains used to come in late May and stay until September. Now it rains unexpectedly and stops too early. We face difficulty following the farming calendars. Sometimes we prepare the land, but before we even sow, the rain disappears. Other times it comes too heavy and washes away our seeds. This unpredictability forces us to take risks like either we sow early and lose everything or wait and miss the growing season. Our fathers used to follow the sky and the winds and knew when to start. Now, even elders cannot predict it, and we are left confused and worried.

This sentiment directly explains the high index value for rainfall variability and its disruptive impact. The increasing temperature was also acutely felt, with a community representative from Woreb Kola noting: "*The average daily temperatures are rising, making field labor in the afternoon increasingly difficult to sustain*."

Furthermore, the quantitative score for flood risk (0.493) was brought to life by personal accounts of asset and crop loss. A community representative in Woramit recalled, "*Two years ago, just before harvest, a flash flood washed away our crops.*" Similarly, a community representative from Zenzelma described how floods damage essential infrastructure as "*We lost tools and harvested maize when the small stream behind our house flooded. We have faced difficulty recovering*."

These localized findings align with and provide micro-level evidence for broader climatic trend analyses for Ethiopia. Studies by Alizadeh (2023) and Almazroui et al. (2020) have documented high spatial and temporal rainfall variability across northeastern Africa. The perceptions of farmers in Bahir Dar and the corresponding high LVI score for precipitation change confirm that these large-scale trends are manifesting as tangible, year-to-year uncertainty at the community level. The observed warming trend is also consistent with projections by Getachew and Manjunatha (2021) for the Lake Tana sub-basin.

Therefore, the exposure component of vulnerability in Bahir Dar is defined by a tangible and disruptive shift in climate patterns. This is not an abstract future risk but a present-day reality that directly impacts the daily lives and agricultural planning of peri-urban farmers, setting the stage for heightened sensitivity to these shocks.

5.3.2. Sensitivity to Livelihood Stressors

Sensitivity, which reflects the degree to which a system is adversely affected by stressors, emerged as the most acute dimension of vulnerability in the study area. With an average index score of 0.586, the livelihoods of peri-urban farmers are inherently and highly susceptible to

disruption. The analysis reveals that this acute sensitivity is primarily shaped by land pressures from urban expansion and a fragile food system, with Addis Alem (0.632) and Woreb Kola (0.621) exhibiting the highest sensitivity (Table 5.3).

The primary driver of sensitivity is the Food component, which scored the highest of any major component in the study (0.662). This is underpinned by two critical indicators; high number of household dependence on family farming for food (0.920) and a high inverse score for total annual production (0.773) (

Figure 5.5). These figures quantify a risky situation where households rely almost exclusively on a production system that is yielding insufficient output. The Water component (0.601) further compounds this sensitivity, reflecting significant challenges in securing consistent water for domestic and agricultural needs.

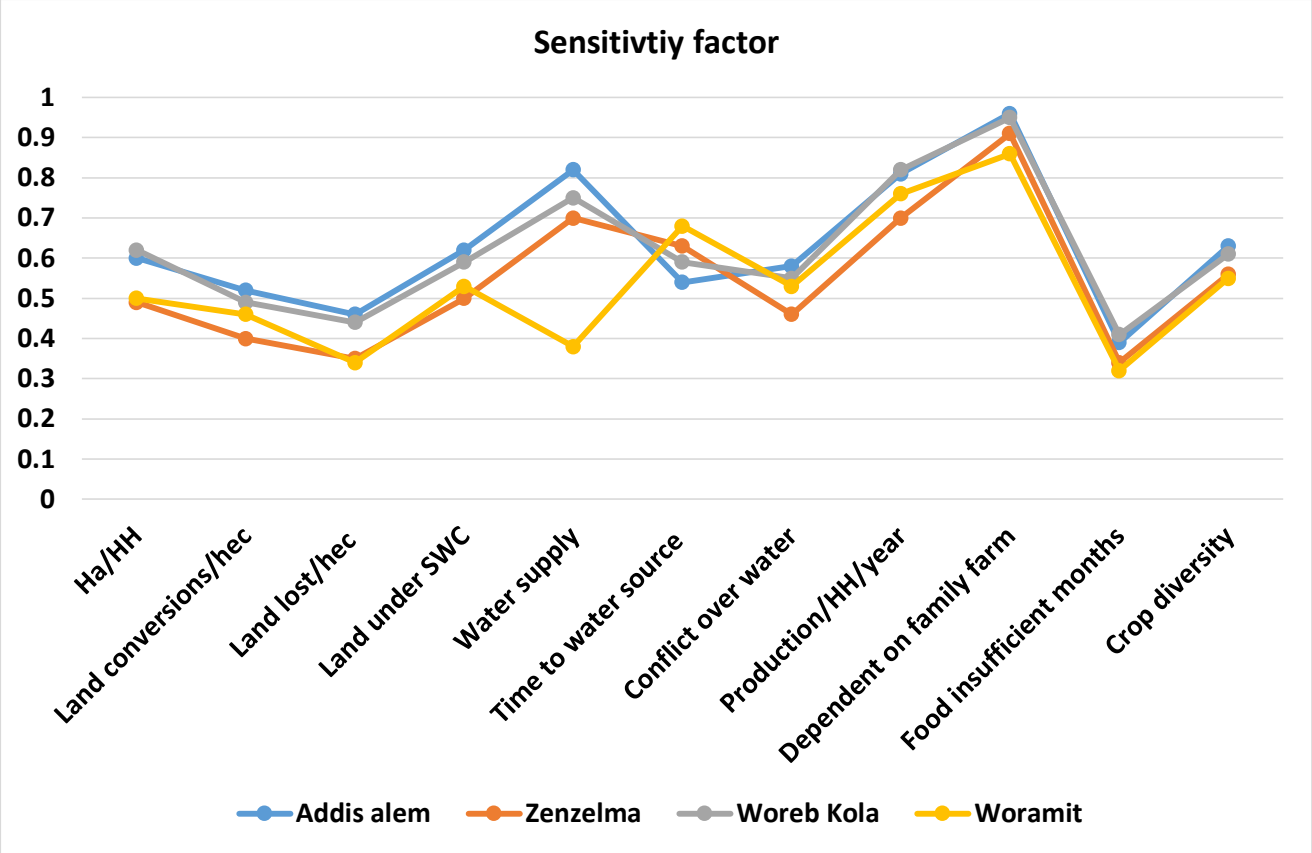


Figure 5.5 Indexed Scores for Sensitivity Sub-Indicators by Kebele

The qualitative data from the FGDs powerfully illustrate the human dimension behind these high sensitivity scores. The high dependence on agriculture means that any disruption translates directly into household crises. As a community representative from Woramit stated,

> Before, we fed our families from the farm. Now, if the market price of grain rises, we go hungry. In the past, we stored enough for the year, but today the harvest does not even last six months. We are forced to buy food from the market, but when the prices increase suddenly, we cannot cope. Families are reducing meals, children are sent to neighbors, and some households even borrow grain on credit until the next harvest. Farming was once our safety; now it is a gamble with weather and markets.

This statement perfectly captures the consequence of high dependence coupled with low production. Farmers directly linked declining yields to both erratic weather and degrading land resources, as noted by a development agent in Addis Alem "*Farmers now farm in small, scattered patches. The yields are not enough to feed family*." This lived experience of declining productivity directly explains the high sensitivity score.

Furthermore, the Land use and sustainability component (0.495) is a critical, underlying driver of this sensitivity, directly linking the non-climate stressor of urban expansion to livelihood fragility. The progressive loss and fragmentation of farmland, quantified by indicators like "Loss of farmland" (0.398) and "Conversion of agricultural to non-agricultural land" (0.468), erodes the fundamental asset base upon which these livelihoods depend. A community representative from Woramit clearly explained this process as "*Our farmland is shrinking year after year. New houses, schools, and roads are taking it.*" This constant pressure reduces the land available for cultivation, making households more sensitive to production failures on their remaining, often smaller and less fertile, plots.

This finding, that non-climate stressors like land fragmentation from urban expansion amplify sensitivity to climate shocks, is consistent with the work of Moisa & Gemeda (2021) and Terfa et al. (2019) in other parts of Ethiopian. The situation in Bahir Dar confirms that the erosion of the natural capital base through urban encroachment creates a state of heightened sensitivity, where even minor climatic variations can trigger significant food and income insecurity. The system has lost its protective capacity, making households acutely vulnerable to the exposures identified in the previous section.

5.3.3. Adaptive Capacity (An Imbalance of Livelihood Capitals)

Adaptive capacity, representing the ability of households to adjust to stressors, is a critical determinant of their overall vulnerability. The study found a moderate but highly constrained average adaptive capacity index of 0.525 (Table 5.3). This aggregate score, however, masks a profound imbalance in the asset portfolio available to peri-urban households, as revealed through an analysis of the five livelihood capitals (Figure 5.6). While communities possess strong human and social capital, these assets are severely undermined by critical deficits in

their physical and financial capital. This asset imbalance is also experienced unevenly across the landscape, with Addis Alem demonstrating the highest adaptive capacity (0.555) and Zenzelma the lowest (0.494). The probable reason for this gap, as indicated by the sub-indicator data in Table 5.3, is Addis Alem's moderately higher scores in Human Capital, particularly in educational attainment and access to extension services, as well as better access to infrastructure and technology. This suggests that proximity to urban services may play a role in shaping a community's ability to respond to the very pressures that urbanization creates.

The strongest assets identified were Human Capital (0.628) and Social Capital (0.554), which act as the cornerstones of community resilience. Human capital is supported by educational attainment (0.590) and extensive farming experience (0.400). The FGDs strengthened this, showing how farmers draw upon generations of experience to navigate current challenges. However, this traditional knowledge is also being tested, as one representative in Zenzelma noted the generational gap as "*Our elders say if the 'Enset' blooms early, rains will come late... However, younger farmers tend to trust meteorological forecasts*." Social capital is particularly strong, rooted in community cohesion with exceptionally high scores for the practice of working together (0.870) and membership in CBOs (0.763). An elderly farmer in Zenzelma explained how this functions as a primary safety net as "*When one of us is in trouble, like losing crops to drought or flood, we call Debo. People bring oxen and labor to help*."

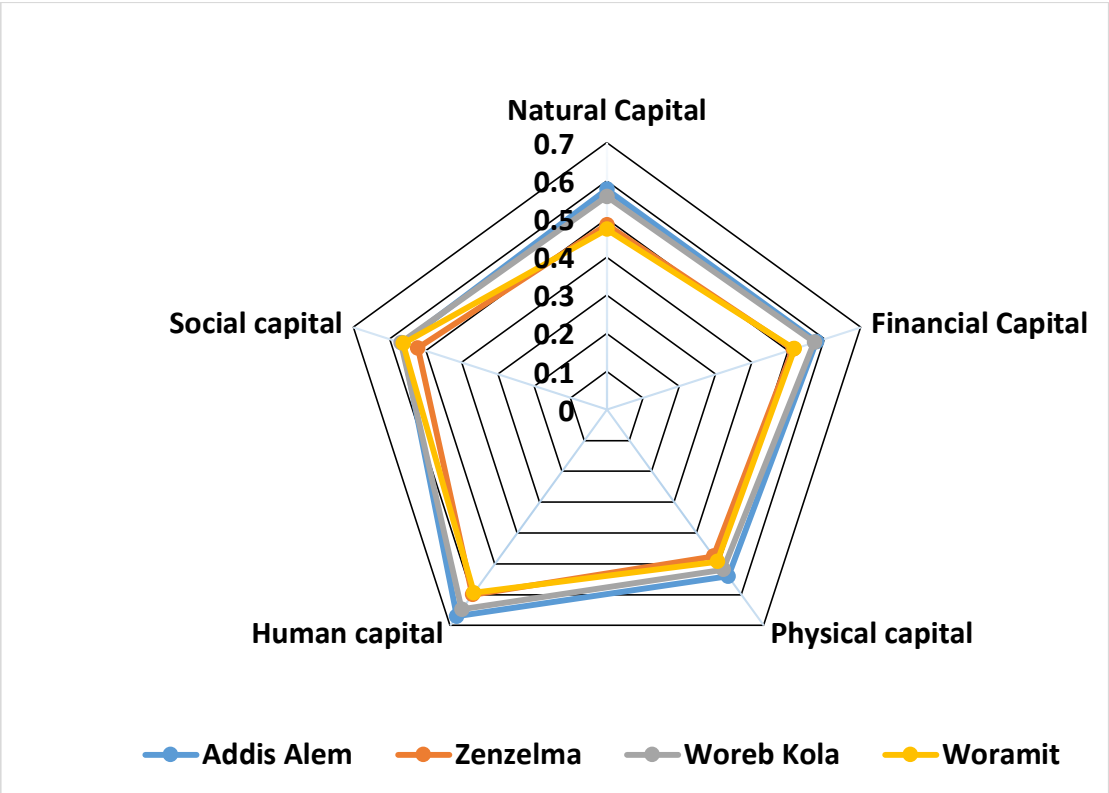


Figure 5.6 Livelihood Capital Asset Pentagon for Peri-Urban Kebeles in Bahir Dar

This erosion of 'bonding' social capital, while a crucial safety net is being lost, is a phenomenon documented in peri-urban interfaces globally as traditional community ties are replaced by market-based economies. As a representative in Woramit observed,

> We still help each other, but the youth are less involved. Most are busy with city jobs or looking for money. Before, when someone lost crops, neighbors brought oxen, seed, or labor without being asked. Now, the young prefer wage work in town, and many do not join these collective efforts. *Debo* and *Wenfel* still exist, but they are weaker, and people cannot rely on them the way our parents did. If we face a big shock, like a flood or crop failure, we cannot solve it through community help alone. We need access to money and credit, but that is missing.

This strain is quantified by the paradoxical pairing of high communal labor with a very low score for access to formal credit (0.448). This finding aligns with the work of Adger (2003) on social capital, illustrating that while strong internal cohesion (bonding capital) is crucial, a lack of connection to external resources and institutions (linking capital) severely limits adaptive capacity.

Compared to these strengths, households face severe limitations in their other assets. Natural Capital (0.524), the very foundation of their livelihood, is the most compromised. This score quantifies the direct impact of the dual pressures of climate change and urban expansion. Rather than just reducing agricultural output, this land loss severely constrains proactive adaptation

strategies. Farmers explained that shrinking plot sizes prevent them from practicing traditional crop rotation or fallowing to restore soil fertility, and eliminate the grazing land needed to maintain livestock as a financial buffer. This erosion of the natural asset base represents a structural constraint that systematically reduces the long-term adaptive potential of the entire livelihood system.

This is intensified by the lowest-scoring asset, Physical Capital (0.508). This score reflects major deficits in essential infrastructure and technology. The lack of access to electricity (0.138) is particularly alarming, as it severely restricts opportunities for modern adaptation. This leads to a classic adaptation gap, where technological solutions like improved seeds (0.660) are available but inaccessible. As an elderly farmer from Woreb Kola expressed, "*Even when we hear about new seeds, we cannot afford them. Loans are only for some*."

Finally, Financial Capital (0.545) is highly constrained. This moderate score is misleading, as it is artificially inflated by the inverse "Food" indicator. The extremely low score for livelihood strategies (0.428) reveals the true state of financial health, highlighting a critical lack of income diversification. The FGDs confirmed this is a distress-driven coping mechanism, not a proactive choice. As a kebele administrator in Zenzelma stated,

> Income from agriculture is no longer predictable. Some of us turned to daily labor or petty trade to survive. But this is not what we want since these jobs are uncertain, low paying, and often take us away from our farms. Sometimes we leave children or wives to manage the land, which lowers productivity further. When drought comes or when the market price of grain rises, we have no savings to fall back on. We feel trapped, working hard but never moving forward.

This narrative underscores how reliance on precarious off-farm activities exacerbates rather than resolves financial fragility. Access to formal financial services to break this cycle is minimal. A community representative explained the barrier "*Credit from the government is hard to get. They ask for land papers or group guarantees, and many of us can't qualify*."

Generally, the asset pentagon for peri-urban farmers in Bahir Dar is heavily skewed. They are relying on strong social cohesion and human experience to navigate a reality where their natural, physical, and financial assets are severely degraded or inaccessible. This imbalance is unsustainable and is the core driver of their vulnerability, a finding consistent with the principles of the SLF, which suggests that a lack of access to a balanced portfolio of assets is a primary characteristic of vulnerability.

5.3.4. LVI-IPCC Estimate (Interplay of Exposure, Sensitivity, and Adaptive Capacity)

The LVI-IPCC synthesizes the three core dimensions of vulnerability by calculating the interaction between exposure, adaptive capacity, and sensitivity. The results show all four kebeles clustered tightly near the zero-threshold, yielding a slightly negative average score of -0.029 (Table 5.4). While mathematically a negative score indicates that adaptive capacity marginally exceeds exposure, the equal-interval classification; based on an objective, symmetrical partitioning of the index range (Moreira et al., 2023; Panthi et al., 2015); places these communities squarely in the 'Moderately Vulnerable' category. This classification is vital for interpretation; it signifies that these communities are not in a position of safety. Rather, they exist in a fragile equilibrium where their constrained adaptive capacity is only just sufficient to offset high exposure. This risky balance is intensified by the extremely high sensitivity of the livelihood system (0.586), which acts as a vulnerability multiplier, ensuring that even minor future shocks; such as a single extreme drought or a new phase of urban land expropriation could easily overwhelm their adaptive capacity and tip the balance towards high vulnerability.

The practical implication of this -0.029 average score is that the 'moderate' classification represents a critical window for targeted policy intervention before these communities lapse into high vulnerability. Rather than a generalized approach, the findings suggest that interventions must be tailored to the specific drivers identified in each kebele (Figure 5.7). For instance, the high exposure in Addis Alem (0.536) and Woreb Kola (0.512) points toward the urgent need for 'Agricultural Buffer Zones' to be formalized within the City Structural Plan to prevent further plot fragmentation. Conversely, the significant physical capital deficits in Zenzelma (0.476) and Woramit (0.493) suggest that local-level priorities should focus on peri-urban electrification and irrigation infrastructure to bolster adaptive capacity. Furthermore, the high sensitivity across all sites implies that compensation for land expropriation is currently insufficient to ensure long-term resilience; the results instead support the establishment of 'Livelihood Transition Funds' that provide vocational training and credit. By addressing these kebele-specific deficits, urban planners can move from reactive land acquisition to proactive, evidence-based resilience building.

Addis Alem emerges as the most vulnerable kebele with an LVI-IPCC score of -0.012. This finding is particularly insightful as Addis Alem also possesses the highest adaptive capacity (0.555). Its position as the most vulnerable is driven by the fact that it simultaneously faces the highest level of exposure (0.536) and the highest sensitivity (0.632). This demonstrates a critical tipping point where the intense pressures of urban expansion and climate variability are beginning to overwhelm the community's coping abilities. The relative contribution of each

vulnerability factor to the composite score is visualized in Figure 5.8, which highlights that Sensitivity is the dominant driver of vulnerability in all four kebeles.

Table 5.4 LVI-IPCC Composite Vulnerability Scores by Kebele

Kebeles	Exposure	Sensitivity	Adaptive Capacity	LVI-IPCC
Addis alem	.536	.632	.555	-0.012
Zenzelma	.422	.553	.494	-0.040
Woreb Kola	.512	.621	.540	-0.017
Woramit	.430	.537	.510	-0.043
Average	**.475**	**.586**	**.525**	**-0.029**

The qualitative evidence reinforces this, with residents describing constant encroachment on their land and increasing livelihood uncertainty. As one long-term resident of Addis Alem explained

> Our plots shrink every year. The boundary between rural and urban is disappearing. What little farmland remains is surrounded by buildings, and farming has become nearly impossible. Many of us have sold part of our land or turned to petty trade, but it's not enough to replace what we lost. We feel caught between the city and the countryside, belonging fully to neither.

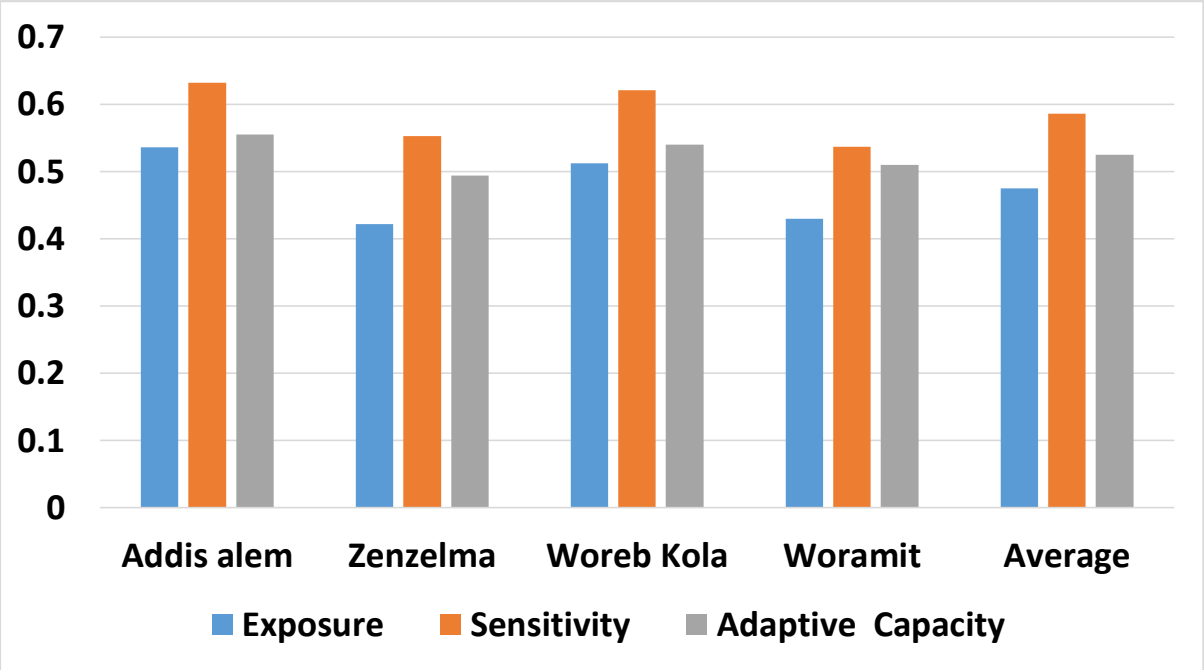


Figure 5.7 Comparison of the three contributing vulnerability factors (Exposure, Sensitivity, and Adaptive Capacity) across the four sampled kebeles

This sentiment captures the lived experience of communities at the frontline of Bahir Dar's urban expansion, where agricultural livelihoods are being displaced and redefined. It aligns with existing literature on peri-urban dynamics, which shows that areas at the urban fringe

experience the greatest land-use competition and market pressures, making them highly vulnerable despite closer proximity to urban services (Kassahun, 2018; Seto et al., 2012).

Conversely, Woramit (-0.043) and Zenzelma (-0.040) were found to be relatively less vulnerable (Figure 5.8). Their lower vulnerability scores are not due to superior adaptive capacities (Zenzelma, in fact, has the lowest). Instead, they are primarily a function of their significantly lower exposure to stressors (0.430 and 0.422, respectively). This suggests that their relative distance from the most intense corridors of urban expansion provides a crucial buffer, allowing their existing adaptive capacities, however constrained, to be more effective in managing the pressures they face. This highlights the critical role that geographical location and the intensity of external shocks play in shaping vulnerability outcomes.

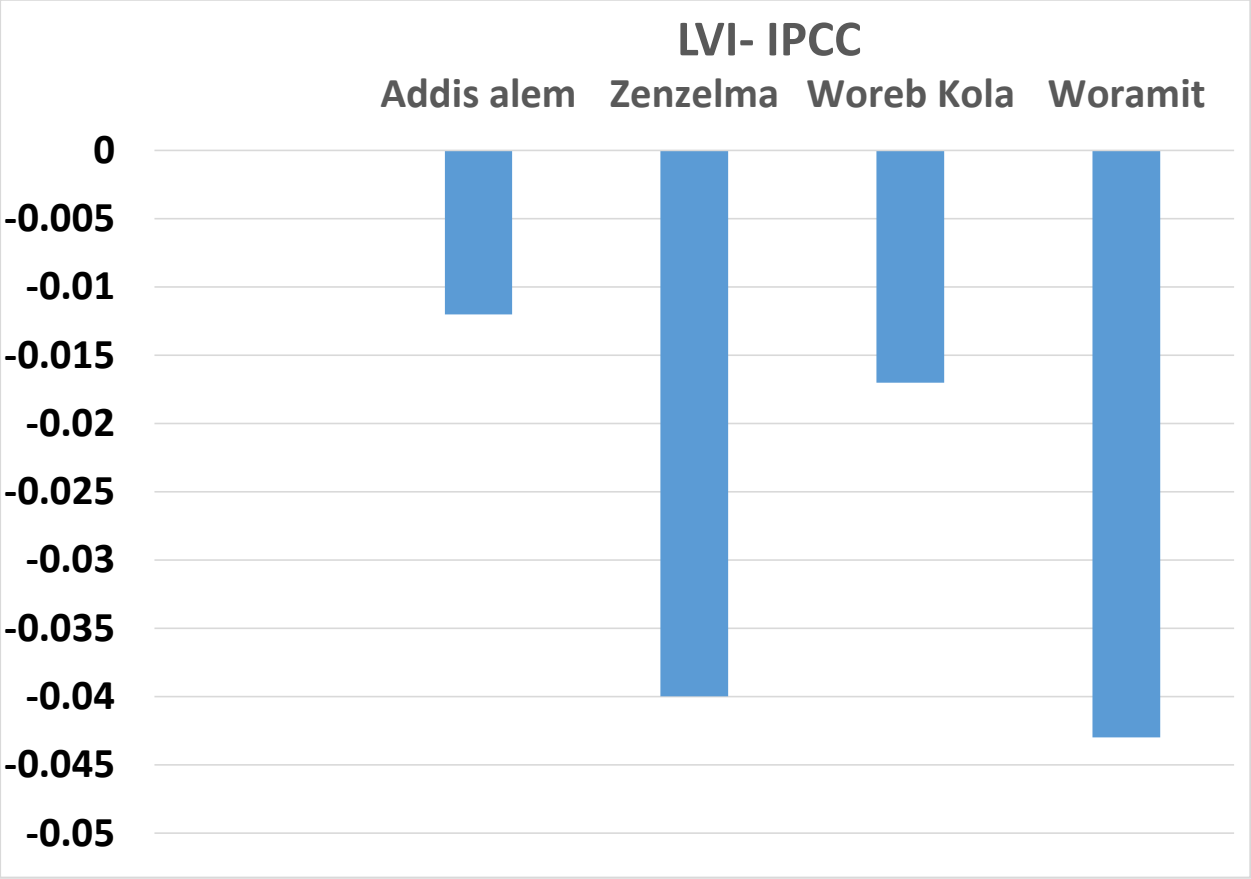


Figure 5.8 LVI-IPCC Composite Vulnerability Scores by Kebele

The most crucial insight from the LVI-IPCC analysis is the role of Sensitivity as a vulnerability multiplier. With an exceptionally high average score of 0.586, sensitivity acts as an amplifier on the net difference between exposure and adaptive capacity. In this context, the high dependence on agriculture and fragile food security means that any shock is magnified throughout the livelihood system. This explains why even in kebeles where adaptive capacity

slightly outweighs exposure (resulting in a negative LVI-IPCC score), the overall situation remains uncertain. The high sensitivity ensures that even a small increase in exposure (e.g., a new expropriation project) or a slight erosion of adaptive capacity (e.g., the decline of a traditional support system) could have a disproportionately large negative impact, potentially driving the system from a state of coping to one of crisis.

As one representative from kebele administrators in Zenzelma explained

> Urban officials plan without talking to farmers. We are the last to know, but the first to suffer. When land is taken, we lose not just soil but our entire way of living. Compensation is delayed or too small, and without alternatives, we are left struggling to feed our families. This makes every new expansion a threat we cannot control.

This lack of agency magnifies household sensitivity and highlights a critical area for policy intervention.

The LVI-IPCC profiles reveals that resilience is not spatially uniform; rather, it is anchored in localized geographical and infrastructural features. For example, while Woramit and Zenzelma appear similarly vulnerable in aggregate, their resilience drivers differ significantly. Woramit's relative resilience to climate shocks is strengthened by its unique micro-geography near Lake Tana, where access to high-value horticultural practices provides a more consistent natural capital buffer than the cereal-based systems in the more arid kebeles. Conversely, Zenzelma exhibits a form of 'institutional resilience'; despite having the lowest adaptive capacity score, its proximity to institutional hubs (university) provides households with more reliable access to informal service-sector jobs, creating a resilience pathway not available in Woreb Kola. This heterogeneous landscape, as visualized in the vulnerability diagram (Figure 5.8), provides the necessary step for policy mapping; it identifies that Addis Alem requires urgent legal land-tenure protection, whereas Woramit requires specialized horticultural water-management support.

Crucially, the vulnerability observed is not merely the sum of two separate stressors, but rather the result of a compounded 'vulnerability trap' created by the interaction of urban expansion and climate variability. The data illustrates a feedback loop; rapid urban encroachment physically removes and fragments high-productivity agricultural land, which systematically erodes the natural capital buffer that peri-urban farmers traditionally used to manage climatic risk. When these households are then exposed to high rainfall variability (0.730), they no longer possess the land-base necessary to absorb production losses. This interaction is further heighted by shifts in financial capital; as urban expansion forces households toward market dependency

for food, climatic shocks that drive up food prices in Bahir Dar's urban markets deliver a dual blow to both subsistence and purchasing power. Thus, urban expansion acts as a structural sensitizer, making the impacts of climate variability more acute while climate variability serves as a distress accelerator, often forcing farmers into the premature sale or lease of their remaining land to urban developers. This synergistic relationship explains why the livelihood system remains in such a fragile equilibrium.

Overall, the LVI-IPCC analysis paints a picture of a peri-urban livelihood system under immense strain (Figure 5.9). The communities are not in a state of collapse but are in a fragile equilibrium, where their resilience is heavily reliant on their internal social and human capital. This resilience, however, is being tested by high and growing exposure to external shocks, and the system's high sensitivity means it has very little capacity to absorb further pressure.

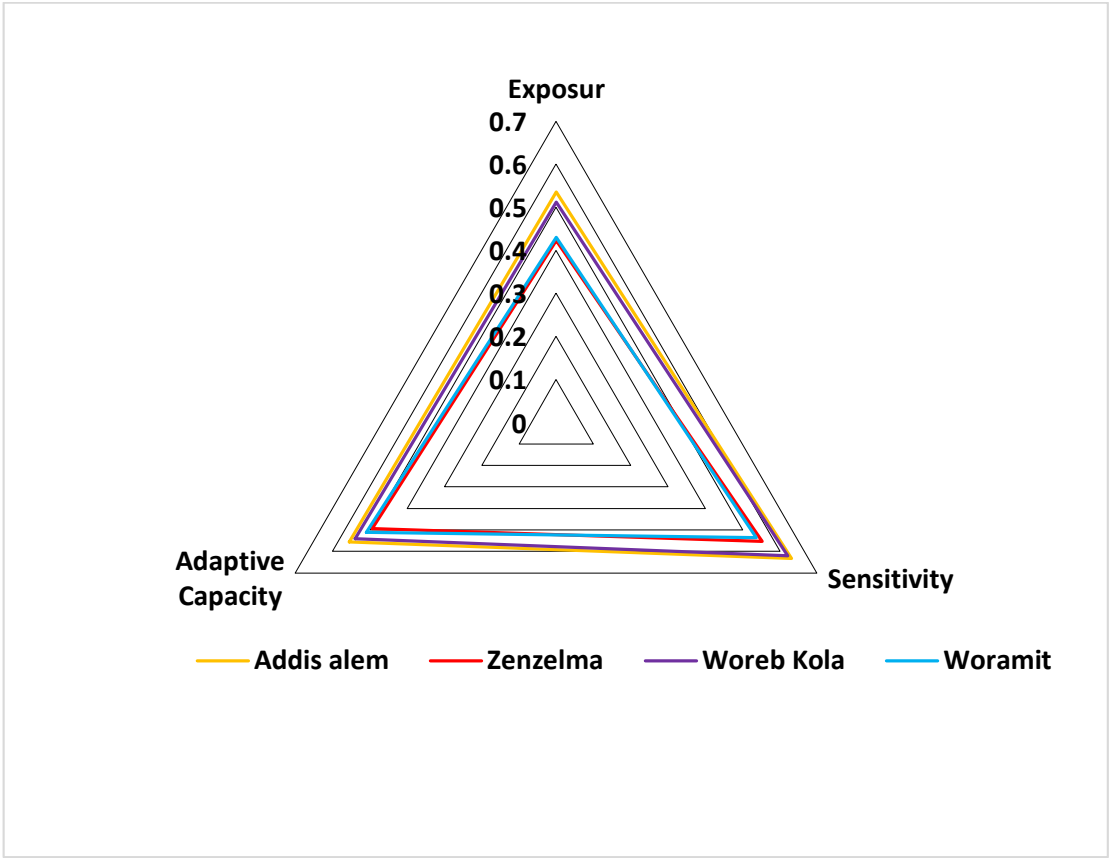


Figure 5.9 Vulnerability by Exposure, Sensitivity, and Adaptive Capacity by Kebele

Beyond the local assessment of Bahir Dar, this study makes a broader conceptual contribution to environmental geography by reframing the 'peri-urban interface.' Traditional vulnerability frameworks have often treated peri-urban areas as static zones in transition; however, our findings demonstrate that this interface is a distinct socio-spatial construct defined by compounded anthropogenic stressors. By successfully operationalizing state-led urban

expansion; specifically land expropriation and tenure insecurity; alongside hydro-meteorological data, the study provide a methodological blueprint for future vulnerability assessments. It demonstrate that in rapidly urbanizing regions of sub-Saharan Africa, urban expansion is not merely an external 'driver' of change, but an active, structural 'vulnerability multiplier.' Our index shows that when urban spatial encroachment erodes the natural capital base, it fundamentally alters the household's susceptibility to climate shocks, rendering standard climate-only vulnerability indices incomplete and potentially misleading for policy design.

Thus, the study moves the field toward a more integrated, 'dual-stressor' approach to understanding resilience. The compounded vulnerability of peri-urban farmers in Bahir Dar can be synthesized into a conceptual framework (Figure 5.10), which highlights how the dual pressures of urban expansion and climate variability interact through the LVI-IPCC framework to produce a fragile equilibrium, while simultaneously identifying the necessary leverage points for targeted policy intervention.

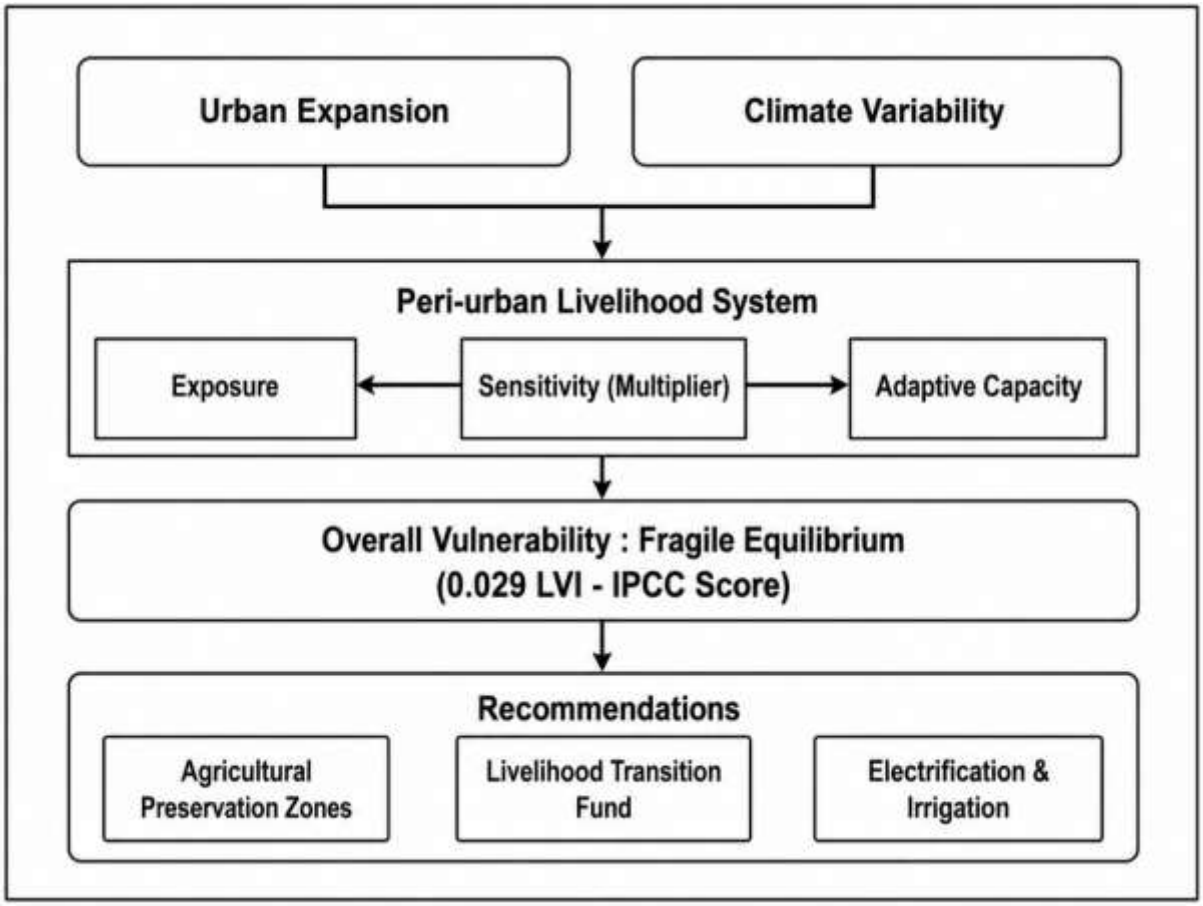


Figure 5.10 Conceptual Flow for assessing Livelihood Vulnerability

5.4. Conclusion

This study assessed the livelihood vulnerability of peri-urban farmers in Bahir Dar, Ethiopia, offering a key conceptual contribution by formally integrating rapid, state-led urban expansion and climate variability within a single, unified peri-urban vulnerability framework. Arguing against standard, climate-only frameworks that treat vulnerability as a strictly hydro-meteorological phenomenon, this study demonstrates that peri-urban vulnerability is a multi-stressor outcome of both climatic and rapid land-use transformations. While farmers possess strong human and social capital, their resilience is systematically undermined by severe deficits in natural, physical, and financial assets; most notably, agricultural land loss, poor infrastructure, and a lack of livelihood diversification. The core conceptual takeaway is that urban encroachment acts as a structural sensitizer that erodes natural capital buffers, which fundamentally amplifies the sensitivity of the entire livelihood system to subsequent climatic shocks, trapping households in high-risk subsistence cycles.

Addressing these vulnerabilities requires moving beyond reactive compensation towards a 'livelihood-first' approach to urban planning. Key actionable takeaways include the urgent need for spatially-explicit interventions, specifically integrating 'Agricultural Preservation Zones' within the city's structural plans to protect productive plots from horizontal sprawl. Furthermore, local governance should leverage existing social capital by institutionalizing traditional safety nets (e.g., Debo and Wenfel) as grassroots cooperatives for credit distribution, and formalize local phenological knowledge into contextualized climate advisory services. Future research should adopt longitudinal and comparative approaches across other Ethiopian cities to track vulnerability pathways over time, providing the evidence base needed to balance rapid urban development with the resilience of peri-urban farming communities.

REFRENCES

Aboye, B. H., Gebre-Egziabher, T., Kebede, B., & Minale, A. S. (2023). Changing farming practices as integral to sustenance and cropland-use loss in the context of urban expansion: The case of Jimma City, Southwest Ethiopia. *Cleaner Environmental Systems*, *9*, 100117. https://doi.org/10.1016/J.CESYS.2023.100117

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Economic Geography*, *79*(4), 387–404. https://doi.org/10.1111/j.1944-8287.2003.tb00220.x

Adigeh, D. T., & Abebe, B. G. (2023). The Practice of Peri-Urban Land Acquisition by Expropriation for Housing Purposes and the Implications: The Case of Bahir Dar, Ethiopia. *Urban Science*, *7*(2). https://doi.org/10.3390/urbansci7020041

Admasu, W. F., Boerema, A., Nyssen, J., Minale, A. S., Tsegaye, E. A., & Passel, S. Van. (2020). Uncovering ecosystem services of expropriated land: The case of urban

expansion in bahir dar, northwest ethiopia. *Land*, *9*(10), 1–20. https://doi.org/10.3390/land9100395

Alemayehu, Z. Y. (2023). Smallholder Farmers Livelihood Vulnerability To Climate Variability, Land Use/Land Cover Change And Adaptation Strategies : Suha Wa Tershed, Northwest Ethiopia : The Case Of Suha Watershed, Upper Blue. In *Dissertation*. Bahir Dar University.

Alemayehu, Z. Y., Minale, A. S., & Legesse, S. A. (2023). Vulnerability of local farmers' livelihood to climate variability across different agro ecology zone in Suha watershed, Upper Blue Nile basin, Ethiopia. *Climate and Development*, *16*(1), 36–53. https://doi.org/10.1080/17565529.2023.2178253

Alizadeh, O. (2023). Changes in the mean and variability of temperature and precipitation over global land areas. *Environmental Research: Climate*, *2*(3), 035006. https://doi.org/10.1088/2752-5295/ACE279

Almazroui, M., Saeed, F., Saeed, S., Nazrul Islam, M., Ismail, M., Klutse, N. A. B., & Siddiqui, M. H. (2020). Projected Change in Temperature and Precipitation Over Africa from CMIP6. *Earth Systems and Environment*, *4*(3), 455–475. https://doi.org/10.1007/S41748-020-00161-X/FIGURES/14

Almulhim, A. I., Bibri, S. E., Sharifi, A., Ahmad, S., & Almatar, K. M. (2022). Emerging Trends and Knowledge Structures of Urbanization and Environmental Sustainability: A Regional Perspective. *Sustainability, MDPI*, *14*(20), 13195. https://doi.org/10.3390/SU142013195

Amare, A. (2018). Linking Vulnerability, Adaptation and Food Security in a Changing Climate: Evidence from Muger Sub-Basin of the Upper Blue-Nile Basin of Ethiopia. In *Dissertation*. Addis Ababa University.

Asmamaw, M., & Debie, E. (2023). Characterizing groundwater quality for a safe supply of water using WQI and GIS in Bahir Dar city, northwest Ethiopia. *Water Practice and Technology*, *18*(4), 859–883. https://doi.org/10.2166/wpt.2023.046

Babbie, E. (2013). The Practice of Social Research. In *Proceedings of the National Academy of Sciences* (Thirteenth). Cengage Learning. http://dx.doi.org/10.1016/j.bpj.2015.06.056%0A

Bahir Dar City Structural Plan Preparation Project Office. (2020). *Population Study Report*.

Berry, B. J. L. (2008). Urbanization. In *Urban Ecology*. springer.

Birara, H., Pandey, R. P., & Mishra, S. K. (2020). Projections of future rainfall and temperature using statistical downscaling techniques in Tana Basin, Ethiopia. *Sustainable Water Resources Management*, *6*(5), 1–17. https://doi.org/10.1007/S40899-020-00436-1/FIGURES/9

Bitana, E. B., Lachore, S. T., & Utallo, A. U. (2023). Vulnerability and Responses of Rural Households to Climate Variability: Agro-Climatic-Based Evidence from Southern Ethiopia. *Sustainability and Climate Change*, *16*(4), 286–301. https://doi.org/10.1089/scc.2023.0053

Braun, V., & Clarke, V. (2006). Thematic analysis revised. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Brenner, N. (2013). Theses on Urbanization. *Public Culture*, *25*(1 (69)), 85–114. https://doi.org/10.1215/08992363-1890477

Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches. In *SAGE Publications Asia-Pacific Pte. Ltd* (Third, Vol. 4, Issue 11). SAGE Publications Ltd. https://doi.org/10.1128/microbe.4.485.1

CSA. (1995). Transitional Government of Ethiopia Office of the Population and Housing Census Commission the 1994 Population and Housing Census of Ethiopia Analytical Report At Addis Ababa Level.Volume 1 Statistical Report. *Central Statistical Authority*.

CSA. (2013). Population Projections for Ethiopia 2007-2037. *Central Statistical Agency Population, Ethiopia*, *July*, 188.

CSA. (2018). Statistical report on the 2018 urban Employment Unemployment survey. *Central Statistical Agency, Ethiopia, October*, 301.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

D'Amour, C. B., Reitsma, F., Baiocchi, G., Barthel, S., Güneralp, B., Erb, K. H., Haberl, H., Creutzig, F., & Seto, K. C. (2017). Future urban land expansion and implications for global croplands. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(34), 8939–8944. https://doi.org/10.1073/PNAS.1606036114

Digafe, B. M., Adam, A. G., & Shibeshi, G. B. (2024). Evaluation of the urban Land use plan's effectiveness in achieving resource efficiency: the case of Bahir Dar city-Ethiopia. *International Journal of Urban Sustainable Development*, *16*(1), 17–34. https://doi.org/10.1080/19463138.2024.2303503

Dodman, D., Hayward, B., Pelling, M., Broto, V. C., & Chow, W. T. L. (2022). *Cities, settlements and key infrastructure*. 907–1040.

Doyle, L., Brady, A. M., & Byrne, G. (2016). An overview of mixed methods research – revisited. *Journal of International Medical Research*, *21*(8), 623–635. https://doi.org/10.1177/1744987116674257

Ellis, F. (2000). Rural Livelihood Diversity in Developing Countries: Evidence and Policy Implications. *Natural Resource Perspective*, *40*.

FAO. (2013). The state of food and agriculture: food systems for better nutrition. *Lancet*, *2*(7929), 313–314. http://www.fao.org/3/i3300e/i3300e00.htm

Gebeyehu, Z., Haji, J., Berihun, T., & Molla, A. (2022). Urban Expansion Impact on Peri-urban Farm Households Welfare in Metropolitan Cities of Amhara National Regional State, Ethiopia. *Ecology, Environment and Conservation*, *28*(1), 33–44. https://doi.org/10.53550/eec.2022.v28i01.005

Geleta, M. (2023). Analysis Of Urban Food Insecurity And Enhancing Households' Resilience To Food Security Shocks In Big Cities Of Northwest Ethiopia. In *Dissertation*. Bahir Dar University.

Getachew, B., & Manjunatha, B. R. (2021). Climate change projections and trends simulated from the CMIP5 models for the Lake Tana sub-basin, the Upper Blue Nile (Abay) River Basin, Ethiopia. *Environmental Challenges*, *5*, 100385.

https://doi.org/10.1016/J.ENVC.2021.100385

Getu, K., & Gangadhara Bhat, H. (2024). Application of geospatial techniques and binary logistic regression model for analyzing driving factors of urban growth in Bahir Dar city, Ethiopia. *Heliyon*, *10*(3), e25137. https://doi.org/10.1016/j.heliyon.2024.e25137

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique. *Global Environmental Change*, *19*(1), 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia. *Landscape and Urban Planning*, *106*(2), 149–157. https://doi.org/10.1016/j.landurbplan.2012.02.016

Huang, X., Huang, X., He, Y., & Yang, X. (2017). Assessment of livelihood vulnerability of land-lost farmers in urban fringes: A case study of Xi'an, China. *Habitat International*, *59*, 1–9. https://doi.org/10.1016/j.habitatint.2016.11.001

Hussey, I., Alsalti, T., Bosco, F., Elson, M., & Arslan, R. (2025). An Aberrant Abundance of Cronbach's Alpha Values at.70. *Advances in Methods and Practices in Psychological Science*, *8*(1). https://doi.org/10.1177/25152459241287123

Idris, M., Kosa, A., & Juhar, N. (2020). Economic linkage between urban development and livelihood of peri-urban farming communities in Ethiopia (policies and practices). *Agricultural and Food Economics*, *8*(1). https://doi.org/10.1186/s40100-020-00164-2

IPCC. (2022a). Climate Change 2022 : Impacts, Adaptation and Vulnerability. In *Working Group II Contribution to the sixth Assessment Report of the IPCC*. Cambridge University Press. https://doi.org/10.1017/9781009325844

IPCC. (2022b). IPCC, 2022: Summary for Policy Makers. *Climate Change 2022: Impacts, Adaptation and Vulnerability*, 1–40. www.ipcc.ch

Kassahun, T. W. (2018). The Impact of Urban Expansion on the Livelihood of Farming Communities in Peri-Urban Area of Bahir Dar City Amahara, Ethiopia,. *Journal of Economics and Sustainable Development ISSN*, *9*(9), 55–64.

Kindu, M., Angelova, D., Schneider, T., Döllerer, M., Teketay, D., & Knoke, T. (2020). Monitoring of Urban Growth Patterns in Rapidly Growing Bahir Dar City of Northwest Ethiopia with 30 year Landsat Imagery Record. *ISPRS International Journal of Geo-Information*, *9*(9), 548. https://doi.org/10.3390/IJGI9090548

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.

Kuma, G. H., Fufa Feyessa, F., & Adugna Demissie, T. (2022). Local climate change indications: Historical trends, multi-model projections and implications in Bilate Catchment, Southern Ethiopia. *IOP Conference Series: Earth and Environmental Science*, *1016*(1). https://doi.org/10.1088/1755-1315/1016/1/012030

Lewte, I. T. (2019). Agroecosystem Based Climate Variability & Change Vulnerability & Adaptation Analysis, And Erosion Hazard Assessment In Fincha'a Sub Basin, Blue Nile Basin, Ethiopia. In *Dissertation*. Addis Ababa University.

Li, Z., Xu, Y., Sun, Y., Wu, M., & Zhao, B. (2020). Urbanization-Driven Changes in Land-Climate Dynamics: A Case Study of Haihe River Basin, China. *Remote Sensing*, *12*(17), 2701. https://doi.org/10.3390/RS12172701

Mekonen, A. A., & Berlie, A. B. (2021). Rural households' livelihood vulnerability to climate variability and extremes: a livelihood zone-based approach in the Northeastern Highlands of Ethiopia. *Ecological Processes*, *10*(1). https://doi.org/10.1186/s13717-021-00313-5

Melesse, A. L. (2023). Climate Change, Vulnerability and Adaptation of Rural Households in Northwest Ethiopia. In *Dissertation*. Addis Ababa University.

Menashe, A., & Bocquier, P. (2021). Urbanization Is No Longer Driven by Migration in Low- and Middle-Income Countries (1985–2015). *Population and Development Review*, *47*(3), 639–663. https://doi.org/10.1111/PADR.12407

Moisa, M. B., & Gemeda, D. O. (2021). Analysis of urban expansion and land use/land cover changes using geospatial techniques: a case of Addis Ababa City, Ethiopia. *Applied Geomatics*, *13*(4), 853–861. https://doi.org/10.1007/S12518-021-00397-W/FIGURES/5

Moreira, L. L., Vanelli, F. M., Schwamback, D., Kobiyama, M., & de Brito, M. M. (2023). Sensitivity analysis of indicator weights for the construction of flood vulnerability indexes: A participatory approach. *Frontiers in Water*, *5*, 970469. https://doi.org/10.3389/frwa.2023.970469

Namgyal, P., Sarkar, S., & Kumar, R. (2025). Vulnerability assessment of rural households to climate change using livelihood vulnerability framework approach in the trans-Himalayan region of Ladakh, India. *Anthropocene*, *49*, 100467. https://doi.org/10.1016/J.ANCENE.2025.100467

Ngu, N. H., Tan, N. Q., Non, D. Q., Dinh, N. C., & Nhi, P. T. P. (2023). Unveiling urban households' livelihood vulnerability to climate change: An intersectional analysis of Hue City, Vietnam. *Environmental and Sustainability Indicators*, *19*(June), 100269. https://doi.org/10.1016/j.indic.2023.100269

Nigani, Z. D. (2020). Evaluating the vulnerability context of livelihoods and responses in a changing climate condition: insights for sustainable livelihood in different agro-ecologies of Gurage Zone. In *Dissertation* (Issue July). Addis Ababa University.

Ofgeha, G. Y. (2021). Land-Use Dynamics And Climate Variability: Local Processes, And Livelihood Implications On Small-Scale Farmers In Anger Watershed, Southwestern Ethiopia. In *Dissertation*. Addis Ababa, Ethiopia.

Pandey, R., Alatalo, J. M., Thapliyal, K., Chauhan, S., Archie, K. M., Gupta, A. K., Jha, S. K., & Kumar, M. (2018). Climate change vulnerability in urban slum communities: Investigating household adaptation and decision-making capacity in the Indian Himalaya. *Ecological Indicators*, *90*(September 2017), 379–391. https://doi.org/10.1016/j.ecolind.2018.03.031

Panthi, J., Aryal, S., Dahal, P., Bhandari, P., Krakauer, N. Y., & Pandey, V. P. (2015). Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. *Regional Environmental Change 2015 16:4*, *16*(4), 1121–1132. https://doi.org/10.1007/s10113-015-0833-y

Poth, C. N. (2018). Innovation in Mixed Methods Research : A Practical Guide to Integrative Thinking with Complexity. *Sage Publications Ltd.*, 1–384.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A Meta-Analysis of Global Urban Land Expansion. *PLOS ONE*, *6*(8), e23777. https://doi.org/10.1371/JOURNAL.PONE.0023777

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(40), 16083–16088. https://doi.org/10.1073/PNAS.1211658109/SUPPL_FILE/PNAS.201211658SI.PDF

Shiferaw, P. A. (2018). Climate-Smart Land Management Decisions in a Changing Climate: Exploring Land Productivity and Livelihood Impacts in the Dabus Sub-basin of the Blue Nile River [Addis Ababa University]. In *Dissertation* (Vol. 2, Issue 1). http://dx.doi.org/10.1038/s41559-019-0877-3%0Aht

Squires, V. R., & Gaur, M. K. (2020). Food security and land use change under conditions of climatic variability: A multidimensional perspective. *Springer International*, 1–355. https://doi.org/10.1007/978-3-030-36762-6

Suryanto, S., & Rahman, A. (2019). Application of livelihood vulnerability index to assess risks for farmers in the Sukoharjo Regency and Klaten Regency, Indonesia. *Jàmbá : Journal of Disaster Risk Studies*, *11*(1), 739. https://doi.org/10.4102/JAMBA.V11I1.739

Talema, A. H., & Nigusie, W. B. (2023). Impacts of urban expansion on the livelihoods of local farming communities: The case of Burayu town, Ethiopia. *Heliyon*, *9*(3), e14061. https://doi.org/10.1016/j.heliyon.2023.e14061

Terfa, B. K., Chen, N., Liu, D., Zhang, X., & Niyogi, D. (2019). Urban Expansion in Ethiopia from 1987 to 2017: Characteristics, Spatial Patterns, and Driving Forces. *Sustainability*, *11*(10), 2973. https://doi.org/10.3390/SU11102973

UNECA. (2018). World Urbanization Prospects 2018 Highlights. *Department of Economic and Social Affairs*.

UNESCO. (2015). Unlocking the Potential of Urban Communities. Case Studies of Twelve Learning Cities. In *National Institute for Lifelong*. https://files.eric.ed.gov/fulltext/ED564060.pdf

United Nations Economic Commission for Africa (UNECA). (2022). SDG Indicators. In *Department of Economic and Social Affairs*. https://unstats.un.org/sdgs/report/2022/goal-11/

World Data Atlas. (2022). *Ethiopia Urban population, 1960-2022*. Knoema. https://knoema.com/atlas/Ethiopia/Urban-population

Yimam, D. A., & Holvoet, N. (2023). Assessing climate change vulnerability of smallholder farmers in northwest Ethiopia: application of a household intrinsic vulnerability index. *International Journal of Climate Change Strategies and Management*, *15*(4), 537–560. https://doi.org/10.1108/IJCCSM-02-2022-0019

CHAPTER 6

6. SYNTHESIS

The Urban Expansion, Climate Governance, and Livelihood Nexus: An Integrative Synthesis of Bahir Dar's Socio-Ecological Vulnerability

6.1. The Need for an Integrated "Nexus" Approach in Regional Cities

Traditional climate change and development literature has consistently suffered from a dual-spatial bias. On one hand, researchers have predominantly investigated rural, agrarian landscapes, treating vulnerability as an exclusively hydro-meteorological phenomenon. On the other hand, urban studies have focused almost exclusively on primary capital megacities, assuming a baseline of institutional capacity and resource abundance that does not exist at the urbanizing frontiers of secondary cities. This gap is particularly critical in the Global South, where rapid, often informal urbanization is concentrated in intermediate and secondary cities. These emerging regional centers, exemplified by Bahir Dar, Ethiopia, represent highly dynamic and volatile socio-spatial interfaces. Here, the physical process of spatial growth collides with localized climate change to produce complex environmental stresses, yet local municipal authorities are poorly equipped to manage them.

To address these challenges, this study argues for the urgent adoption of an integrated "nexus" approach that systematically links three distinct domains; physical urban expansion, institutional climate governance, and human livelihood vulnerability. Historically, environmental studies have operated within disciplinary silos. Geospatial analysts map LULC changes and surface temperatures without examining the institutional failures that permit ecological degradation; public administration scholars evaluate policy frameworks without grounding them in spatial realities; and development practitioners measure household vulnerability without analyzing the structural institutional constraints that limit adaptive capacity. This fragmented approach is both conceptually inadequate and practically misrepresentative, as separate and isolated policy interventions are highly likely to be unsuccessful. For instance, a municipal policy focused on urban greening will have minimal impact if the institutional capacity and regulatory enforcement to protect green spaces from speculative encroachment do not exist.

By adopting a convergent mixed-methods design, this paper moves beyond these disciplinary boundaries to illustrate how biophysical processes are mediated by socio-political realities. In regional cities like Bahir Dar, the physical environment, municipal governance, and peri-urban

livelihoods do not exist as independent systems; they are deeply and causally interconnected. Uncontrolled spatial sprawl is an active, structural "vulnerability multiplier" that systematically erodes the natural capital buffer traditionally used by peri-urban farmers to manage climatic risks. When these natural assets are depleted, even minor climate anomalies are magnified into acute livelihood crises. Therefore, understanding and building urban resilience requires a holistic framework capable of tracing this entire causal chain; from the physical landscape, through the institutional structure, to the human cost.

6.2. The Causal-Chain Framework

To theoretically and empirically ground this integration, a multi-dimensional conceptual model based on a causal-chain logic was developed (Figure 6.1). This framework consolidates the study's four specific research objectives into a single, cohesive socio-ecological system. Moving from macro-level socio-demographic drivers to physical spatial processes, it traces how these forces are mediated by local institutions before manifesting as livelihood outcomes at the peri-urban interface. Rather than operating as independent studies, the four constituent papers of this project serve as the empirical building blocks of this causal chain, where the statistical and qualitative findings of each objective validate the structural pathways of the entire system.

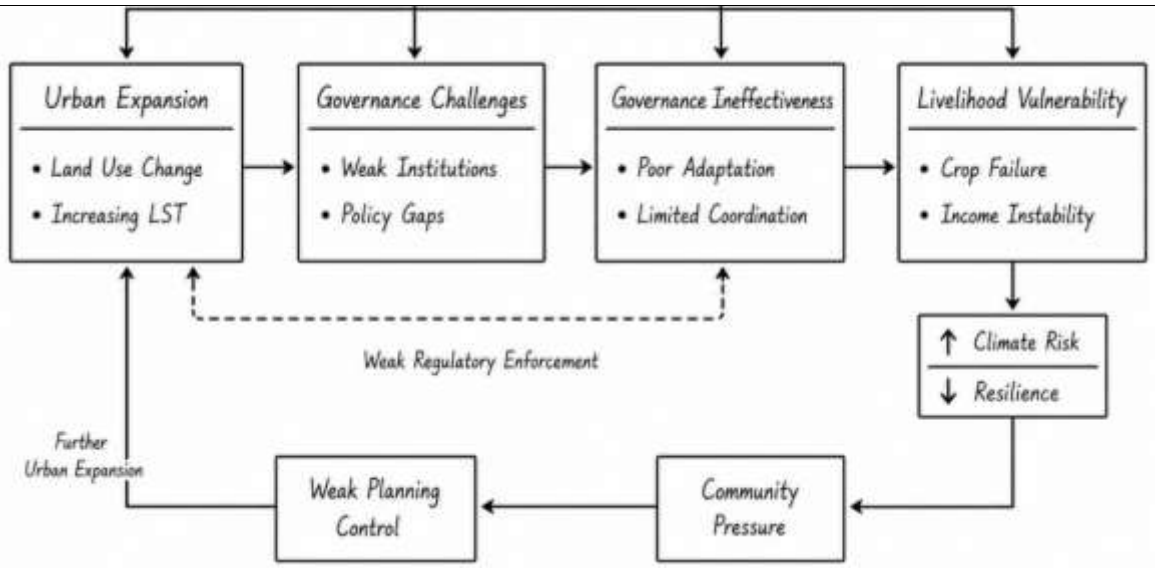


Figure 6.1 The Integrated Socio-Ecological Causal-Chain of Urban Climate Vulnerability

The first link in this causal chain is the biophysical and spatiotemporal transformation of Bahir Dar's landscape. Over the forty-year study period (1984-2024), built-up areas expanded by 366%, a trajectory accelerated by the city's 1994 designation as the regional capital. This rapid

spatial sprawl drove severe microclimatic warming; built-up areas recorded a 6.0°C increase in mean LST, accompanied by a 34% decline in wetlands and a 3.2°C rise in vegetated surface temperatures. This thermal intensification is statistically confirmed by the strong positive correlation of the built-up index (NDBI) with LST, and the weakening negative correlations of the vegetation (NDVI) and water (MNDWI) indices, proving that rapid horizontal expansion has systematically dismantled the city's natural thermal regulating buffers.

This biophysical transformation is mediated by the local urban governance framework, which is critically inadequate to manage such environmental stress (Overall UCG Index = 0.489). Although formal accountability mechanisms exist on paper (RII = 0.639), they are neutralized by a near-total failure in regulatory enforcement (RII = 0.400), making enforcement the weakest link in the governance chain (Melese et al., 2026a). This systemic weakness is compounded by a profound vertical disconnect; a statistically significant perceptual gap (ANOVA p = 0.036) exists between regional planners (M = 0.53) who view awareness-raising efforts favorably, and local implementers (M = 0.48) who perceive widespread failure on the ground. This gap empirically demonstrates that the city's administrative machinery is decoupled, leaving high-level national policy targets insulated from municipal enforcement realities.

To explain this institutional failure, the causal chain incorporates key structural constraints. SEM shows that eight institutional constraints explain 65% of the variance in perceived governance effectiveness (R^2=0.65), with Human Resources and Capacity (HIC, β=−0.312) identified as the single most critical bottleneck, followed closely by Policy Deficiencies (PRF, β=−0.285) and Weak Political Will (PWC, β=−0.276). Qualitatively, these barriers manifest as a "Financial Paralysis Trap" (RII = 0.304) and a "Capacity-to-Enforcement Failure Loop," where chronic resource deficits starve municipal departments of the funding needed to retain technical experts. This operational incapacity prevents the contextualization and enforcement of planning laws, transforming the local UCG framework into a porous filter that allows unmitigated urban expansion to encroach onto the peri-urban fringe.

This regulatory environment has direct human consequences for frontline peri-urban farming communities. The LVI-IPCC assessment reveals a state of moderate, precarious vulnerability (average LVI-IPCC = -0.029), where extremely high sensitivity (0.586) is driven by an intense reliance on rain-fed agriculture (0.780) on a rapidly shrinking land base. This land depletion is the direct spatial outcome of the unmanaged urban sprawl mapped in the physical analysis.

Furthermore, the farmers' adaptive capacity (0.525) is severely constrained by deep-seated deficits in physical capital (such as a lack of electricity and irrigation) and financial capital (limited credit access and low income diversification). This asset imbalance is a direct consequence of local governance failures; an under-resourced, politically unstable city administration cannot enforce its master plan, nor can it provide the basic infrastructure and credit systems needed to support local adaptation.

Ultimately, this study demonstrates that peri-urban vulnerability is not an inherent condition, but an actively constructed "vulnerability trap" driven by the synergistic interaction of physical land transformation and systemic institutional failure. This relationship is highly non-linear; increasing livelihood vulnerability intensifies pressure on municipal systems through growing demands for infrastructure and social protection. While governance failures accelerate uncontrolled spatial expansion, which further undermines institutional capacity. Therefore, the urban-climate-livelihood nexus in Bahir Dar operates as a dynamic, socio-ecological feedback system rather than a simple, one-directional causal sequence.

6.3. Systemic Themes of the Nexus

The multi-dimensional challenges facing Bahir Dar cannot be understood through isolated, disciplinary assessments. By synthesizing the spatiotemporal, institutional, and household data, three overarching, interdisciplinary themes emerge. These themes illustrate how physical urban expansion, institutional constraints, and human vulnerability are not separate crises, but rather deeply connected components of a single, failing socio-ecological system.

6.3.1. The "Hollow Core" of Spatial Regulation and Microclimatic Warming

The most visible manifestation of Bahir Dar's socio-ecological crisis is the rapid degradation of its physical and thermal landscape, a process that cannot be separated from the city's regulatory enforcement deficit (Melese et al., 2025, 2026a, 2026b). The 40-year spatial analysis reveals a 366% surge in built-up area and a 34.2% decline in wetlands, which directly drove a 6.0°C rise in mean built-up surface temperature. This biophysical warming is statistically confirmed by the weakening negative correlation between LST and MNDWI, indicating that urban encroachment has severely compromised the thermal buffering capacity of the city's blue-green spaces.

However, this physical landscape transformation is not merely an inevitable spatial by product of population growth; it is the spatial footprint of what local stakeholders describe as a "hollow core" of spatial planning. This "hollow core" refers to a state where climate-sensitive policies

and land-use regulations exist on paper but lack any functional enforcement mechanisms at the municipal level. The institutional evaluation directly validates this connection; while formal planning policies exist, Climate Change Law and Enforcement registered the lowest score of any governance dimension (RII = 0.400). The real-world consequence of this "hollow core" and enforcement deficit was starkly illustrated by field observations and community interviews, which documented multiple instances of residential and commercial construction encroaching directly into natural wetlands and drainage channels in direct violation of the city's master plan.

When the local governance system fails to enforce its spatial rules, it acts as a porous filter, letting unmanaged spatial sprawl consume the natural capital buffers (wetlands and vegetation) that peri-urban farmers traditionally used to insulate themselves from climatic hazards. Thus, the physical UHI effect and the social sensitivity of farmers are structurally permitted and exacerbated by this regulatory "hollow core".

6.3.2. The "Financial Paralysis Trap" and the fragile of Adaptive Capacity

The second systemic theme connects the institutional constraints of municipal governance directly to the asset deficits that cripple the adaptive capacity of peri-urban households. Our path analysis (SEM) reveals that Financing and Budget Allocation (FBA, $\beta = -0.241$, $p = 0.003$) is a highly significant constraint on governance effectiveness. Qualitatively, this is expressed as a "Financial Paralysis Trap," where municipal environmental departments are starved of funding because the city’s core budgetary processes prioritize short-term, politically visible infrastructure over climate adaptation.

This institutional financial starvation directly mirrors, and causally drives, the severe asset deficits observed at the household level. The livelihood assessment shows that the adaptive capacity of peri-urban farmers is highly constrained (0.525), characterized by a profound deficit in Physical Capital (0.508) and Financial Capital (0.545).

The institutional-to-social link is direct; because the city administration is in a financial problem, it fails to invest in the basic public infrastructure needed to support sustainable adaptation at the urban fringe. This is quantified by the extremely low household score for access to electricity (0.138) and the lack of small-scale irrigation technologies, which prevents farmers from translating their extensive human capital (farming experience) into sustainable, climate-resilient practices.

Furthermore, the city's inability to mobilize resources prevents the establishment of formal credit systems, leaving households with an exceptionally low score for access to formal credit (0.448). Starved of both institutional and household financial capital, farmers are unable to invest in adaptive technologies like improved seeds, trapping them in low-return, rain-fed agriculture.

6.3.3. Inconsistent Political Will and the Decline of Social Safety Nets

The final systemic theme connects the socio-political instability of the governance framework to the erosion of the traditional social networks that represent the final line of defense for vulnerable communities. The SEM identifies Political Will and Commitment (PWC, $\beta=-0.276$) as a powerful institutional barrier, which is qualitatively defined by a highly reactive, personalized, and inconsistent governance style.

Because climate governance is personality-driven rather than institutionalized, high leadership turnover acts as a systemic "reset button". Every time a mayor or bureau head changes, climate-relevant projects, even those with external funding, lose momentum or are re-prioritized entirely, erasing previous progress and active institutional memory.

This institutional unpredictability and "governance by disaster" (where climate issues only gain political attention during extremes) directly destabilizes the social fabric of the peri-urban interface. As urban expansion unchecked by consistent planning encroaches on agricultural lands, it monetizes the local economy, forcing households into precarious, low-paying daily labor or petty trade to survive.

This distress-driven economic shift has triggered an erosion of traditional, informal social safety nets. While the quantitative social capital score remains relatively high due to traditional mutual-aid practices (such as Debo and Wenfel, RII = 0.870), qualitative focus groups reveal that these networks are under severe strain.

Younger, land-displaced farmers are increasingly disengaging from these reciprocal community labor networks, preferring informal wage work in the city center to secure immediate cash. Thus, the "reset button" of leadership instability at the municipal level, combined with unchecked spatial market forces, is actively dismantling the community cohesion and social safety nets that once served as the cornerstones of peri-urban resilience.

6.4. Contributions to Knowledge

The overarching contribution of this study lies in its integrated synthesis of physical landscape dynamics, municipal governance constraints, and household vulnerability into a unified, empirically grounded narrative of urban climate resilience in secondary cities of the Global South. Specifically, this study presents three core, interdisciplinary takeaways; first, rapid microclimatic warming is an active spatial signature of local planning and enforcement failures; second, rapid urban sprawl acts as a "structural sensitizer" that fundamentally alters climate-only vulnerability models; and third, the "instability paradox" in sub-national governance highlights a severe decoupling between policy design and operational implementation.

The first major conceptual takeaway is that physical microclimatic changes are active spatial signatures of local regulatory enforcement failures. While urban climate science traditionally treats rising surface temperatures as purely biophysical outcomes, this research proves that Bahir Dar's 6°C rise in built-up LST is directly enabled by a severe local enforcement deficit, exemplified by the critically low score for Climate Change Law and Enforcement (RII= 0.400). By showing how the "hollow core" of planning regulations allows physical concrete to encroach into natural cooling wetlands and vegetation, this study demonstrates that landscape warming is a physical manifestation of institutional weakness, demanding a paradigm shift that integrates spatial remote sensing with rigorous municipal capacity diagnostics.

The second key takeaway is that rapid urban expansion acts as an active, structural "vulnerability multiplier" and "structural sensitizer" that invalidates standard, climate-only vulnerability assessments. Moving beyond traditional models that treat vulnerability primarily as a rural, hydro-meteorological phenomenon, this study proves that at the urban-rural interface, state-led land expropriation and tenure insecurity are the primary drivers of extreme household sensitivity (0.586). By integrating LVI-IPCC and Sustainable Livelihoods perspectives, the study demonstrate that when urban spatial encroachment erodes a household's natural capital base, it fundamentally alters their physical and financial coping capacity, leaving them unable to absorb subsequent climate shocks. Standard, climate-only indices are therefore incomplete, as they fail to capture how spatial-administrative transformations actively manufacture human precarity.

The third and final takeaway is the theoretical conceptualization of the "unfunded mandate" and the "instability paradox" in sub-national climate governance. This investigation contributes

to Multi-Level and Adaptive Governance theories by illustrating the structural barriers that prevent national plans (like the NAP-ETH) from being realized at the local level. Specifically, the study conceptually resolves the "Instability Paradox" by demonstrating that while regional political instability may appear statistically insignificant ($p = 0.124$) in daily administrative operations, it acts as an acute, latent threat. As expressed by local officials, instability does not alter the "software" of governance (policies exist), but it completely shuts down the operational "hardware" (implementation, funding, and partnerships). Compounded by a severe lack of fiscal autonomy, this structural disconnect locks secondary cities into a perpetual state of reactive "governance by disaster".

Ultimately, this study demonstrates that urban climate vulnerability in secondary cities is not merely a consequence of climatic hazards, but is co-produced through the synergistic interaction of rapid urban expansion, weak governance systems, and declining livelihood resilience. Effective climate action therefore requires integrated interventions that simultaneously address spatial planning, institutional capacity, and livelihood adaptation.

.

CHAPTER 7

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

Bahir Dar's transition into a regional capital has acted as an unprecedented catalyst for ecological and microclimatic degradation. The core physical conclusion of this research is that rapid, unchecked urban expansion; characterized by a 366% increase in built-up area over forty years; has systematically dismantled the city's natural climate resilience. By replacing critical cooling landscapes like wetlands and vegetation with impervious surfaces, the post-capital development trajectory has directly intensified the UHI effect, resulting in a mean LST increase of 6.0°C in built-up areas. The significance of this finding lies in its empirical proof that administrative and political designation in secondary cities, when left unmanaged by active spatial planning controls, acts as a primary driver of rapid microclimatic deterioration rather than sustainable urban growth.

Underlying this physical degradation is a fundamentally ineffective UCG framework that represents a primary barrier to climate resilience rather than a solution. The institutional evaluation reveals a stark 'policy-implementation chasm' where formal administrative structures and basic accountability mechanisms exist on paper, but actual law enforcement remains the weakest link (RII = 0.400). The main conclusion to be drawn here is that this systemic failure is driven by a clear, self-reinforcing hierarchy of structural constraints; a profound deficit in local human capacity (manifested as a lack of specialized expertise and high staff turnover), a hollow core of policies that lack local specificity, and a reactive, crisis-driven political will that treats climate action as a secondary priority. This is highly significant for the wider climate governance discourse, as it proves that the mere existence of national climate strategies (like the NAP-ETH) is entirely insufficient; without local fiscal autonomy, staff retention incentives, and non-partisan institutional structures, policy design remains permanently decoupled from local enforcement realities.

The human cost of these combined physical and institutional failures is a state of extreme, compounded vulnerability for peri-urban farming communities. The primary conclusion regarding these communities is that their traditional social and human capital; while strong on an internal level through traditional labor-sharing networks like Debo; is being systematically overwhelmed by severe structural deficits in natural, physical, and financial assets. The progressive loss of agricultural land to urban sprawl, combined with highly unpredictable

climate patterns, has stripped these households of their protective resource buffer, locking them into low-return, distress-driven coping strategies. This vulnerability is not an inherent or natural condition, but rather a direct, structural consequence of municipal governance failures that have systematically neglected to invest in local infrastructure, extension services, and secure land tenure for marginalized citizens at the urban-rural frontier.

Ultimately, this research leads to a powerful and sobering meta-conclusion; the unmanaged physical expansion of Bahir Dar, enabled by an ineffective and resource-starved governance system, is creating a self-reinforcing vulnerability trap. Physical environmental degradation, institutional paralysis, and social vulnerability are not separate crises but deeply intertwined components of a single, failing socio-ecological system. The theoretical significance of this work lies in its empirical validation of how these dimensions collide at the urbanization frontier of the Global South. By presenting a ground-truthed diagnostic of these linkages, this dissertation demonstrates that achieving sustainable urban futures in rapidly growing secondary cities requires more than incremental adjustments; it demands a strategic, legally-binding alignment of national climate ambitions with empowered, localized, and well-resourced institutional capabilities.

7.2. Recommendations

7.2.1. Recommendations for Policy and Practice

To transition from reactive, separate measures to a proactive, integrated, and multi-scalar approach to urban climate resilience in Bahir Dar, the following institutional actions are recommended

- To the Bahir Dar City Land Development and Management Office (in coordination with ANRS Bureau of Urban Development & Infrastructure)
    - ✓ Develop and Enforce a Climate-Sensitive Master Plan: Legally integrate spatial climate data into the city's long-term master plan to restrict spatial encroachment on vital ecological buffers and natural water pathways.
    - ✓ Designate and Protect Peri-Urban Greenbelts: Formally demarcate and protect a peri-urban agricultural greenbelt to serve the dual purpose of protecting local livelihoods and acting as green infrastructure to mitigate the local UHI effect.
- To the Bahir Dar City Administration & ANRS Environmental Protection and Green Development Authority

- ✓ Establish a Dedicated Municipal Climate Action Unit: Create a permanent, legally empowered, inter-departmental unit within the city administration to coordinate environmental, planning, agricultural, and public works initiatives.
- ✓ Implement Municipal Capacity and Staff Retention Programs: Partner with Bahir Dar University to offer continuous technical training in climate science and GIS modeling, while implementing professional incentives (salary scales or career paths) to reduce high staff turnover.
- ✓ Bridge the Policy-Implementation Gap: Enact localized city-level regulations that include clear mandates, dedicated budget lines, and transparent, strict enforcement mechanisms to translate national strategies (like the NAP-ETH) into local practice.

- To the Bahir Dar City Agriculture Office & Local Financial Cooperatives (e.g., Amhara Credit and Saving Institution)
  - ✓ Facilitate Agricultural Modernization: Invest in physical assets for peri-urban farmers, specifically expanding access to small-scale irrigation technologies and climate-resilient crop varieties to reduce reliance on erratic rain-fed agriculture.
  - ✓ Reform and Expand Microfinance Services: Design tailored micro-credit and crop insurance products for vulnerable peri-urban farmers, removing restrictive collateral requirements (such as formal land-ownership papers) that currently disqualify smallholders.
  - ✓ Support Non-Farm Livelihood Diversification: Provide targeted skills training and start-up micro-grants for off-farm activities to reduce the community's absolute sensitivity to climate and land shocks.
- To the Bahir Dar City Finance Office (in coordination with ANRS Bureau of Finance)
  - ✓ Launch a Dedicated Municipal Resilience Fund: Establish a sustainable local fund funded by dedicated environmental levies on new high-density urban developments.
  - ✓ Formulate Public-Private Partnerships: Partner with local agro-processing, real estate, and tourism sectors to co-fund community-level climate adaptation projects.
- To Joint Stakeholders (City Administration, Academia, and CSOs)
  - ✓ Institutionalize a Multi-Stakeholder Platform: Establish a permanent, non-tokenistic platform where peri-urban community representatives can actively participate in spatial planning and climate resilience decisions.

7.2.2. Recommendations for Future Study

While this study provides a comprehensive diagnosis of the challenges facing Bahir Dar, it also boosts several paths for future research that would deepen and expand upon its findings. Firstly, given that this study's vulnerability assessment represents a cross-sectional snapshot, there is a clear need for longitudinal studies. Tracking the livelihood vulnerability of the same peri-urban communities over a period of five to ten years would provide invaluable insights into the dynamic nature of vulnerability, the effectiveness of adaptation strategies over time, and the long-term impacts of ongoing urban expansion. Secondly, the findings of this investigation would be significantly enriched by comparative case studies. Replicating this integrated assessment in other rapidly expanding Ethiopian regional capitals, such as Hawassa or Adama, would help to distinguish between context-specific local factors and systemic challenges common to the nation's urban development model, thereby enhancing the generalizability of the conclusions.

Furthermore, this study identified a lack of political will as a critical underlying constraint to effective governance. Future research could build upon this finding by employing a detailed political economy analysis to investigate the specific interests, power dynamics, and informal incentive structures that shape urban land development and environmental policy in Bahir Dar. Such an inquiry would help to uncover the deeper, often hidden, reasons for the persistent implementation gap. Finally, more detailed study is needed on the social and economic consequences of land expropriation and the adequacy of current compensation mechanisms in the peri-urban zone. A detailed study focusing on whether existing legal frameworks for compensation enable genuine livelihood reconstruction or inadvertently deepen poverty would provide critical evidence for designing more just and equitable urban expansion policies.

Appendixes

Bahir Dar University

Faculty of Social Sciences

Department of Geography and Environmental Studies

Appendix 1: Tool 1: Survey Questionnaire for Expert Respondents

This questionnaire is designed as part of an academic research study at Bahir Dar University, Department of Geography and Environmental Studies. The aim is to gather expert opinions to assess the effectiveness and institutional constraints of urban climate governance in Bahir Dar City. The findings of this study will contribute to the academic body of knowledge and offer practical recommendations to enhance climate governance in rapidly urbanizing contexts. Your responses will be kept strictly confidential and will be used solely for academic purposes. The information you provide will be anonymized and presented in aggregate form only.

Instructions

Please indicate your level of agreement by marking (√) with each statement by selecting the appropriate response on the 5-point Likert scale provided. 1 = Strongly Disagree, 2=Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree

Thank you for your valuable time and contribution

Part I: Background Information of Respondents

1. Sex: 1. Male 2. Femal
2. Age: _____
3. Highest Educational Qualification:_____
4. Main Area of Expertise: _____
5. Current Position/Title: _____
6. Years of Professional Experience:_____
7. Institutional Affiliation: _____

Part II: Institutional Effectiveness of Urban Climate Governance

Indicators of Climate Change Governance		Responses				
		1	2	3	4	5
1. Accountability						
1.1	Government bodies are held accountable for decisions that exacerbate climate change					
1.2	Authorities are held accountable for violations of laws related to climate change protection					
1.3	Government institutions are responsive to the needs of communities vulnerable to climate change					
1.4	There is a budget performance audit for climate change activities within government institutions					
2. **Participation**		1	2	3	4	5
2.1	The private sector participates actively in planning climate change governance measures					
2.2	Civic associations are involved in planning climate change governance measures					
2.3	Local communities participate in climate change response actions					
2.4	Public forums about climate change issues are regularly organized					
2.5	Community-based organizations (CBOs) play a key role in climate change governance					
2.6	There is effective involvement of various government offices in climate change governance					
2.7	Collaboration between NGOs, local communities, and the private sector is strong in climate change governance					
3. **Equity**		1	2	3	4	5
3.1	There are policies in place that ensure the poor are considered in climate change response efforts					
3.2	Women are actively involved in climate change governance activities					
3.3	All communities, regardless of socioeconomic status, have equitable access to climate-related resources					
3.4	Marginalized groups are actively included in climate change decision-making processes					
3.5	Specific adaptation and mitigation measures are designed to address the unique vulnerabilities of groups					
3.6	The benefits of climate action are equitably distributed across the city					
3.7	The allocation of resources for climate action is transparent and accountable					
3.8	Climate change adaptation measures consider the impact on vulnerable groups					
4. Awareness Raising		1	2	3	4	5
4.1	There are awareness-raising campaigns targeting key actors involved in climate change measures					
4.2	Awareness campaigns targeting the general community about climate change are frequent and effective					
4.3	The public is well-informed about specific actions they can take to address climate change					

4.4	There are sufficient training opportunities for experts involved in climate change governance					
4.5	The training provided to experts on climate change governance is effective in building capacity					
5. Institution		1	2	3	4	5
5.1	Environmental institutions have the capacity to coordinate environmental protection activities effectively					
5.2	Local-level institutions have sufficient power to make decisions regarding climate change governance					
5.3	Upper-level government provides adequate support for local climate change governance initiatives					
5.4	Environmental institutions have adequate resources to coordinate climate change governance activities					
6. Adaptability		1	2	3	4	5
6.1	There are regular training opportunities on climate change adaptation and mitigation measures					
6.2	Roles and responsibilities related to climate change response measures are clearly defined					
6.3	Actors involved in climate change governance participate actively in adaptation and mitigation measures					
6.4	Urban climate governance plans and policies are flexible and can adapt to changing climate projections					
6.5	Local and indigenous knowledge about climate adaptation is effectively integrated					
6.6	Stakeholders have access to the technology and information needed for effective adaptation					
6.7	Local institutions have effective mechanisms for mobilizing and accessing financial resources					
6.8	Mechanisms are in place to monitor and evaluate the success of climate adaptation measures					
6.9	The city has sufficient resources and capacity to respond effectively to climate extremes					
7. Climate Change Law and Enforcement		1	2	3	4	5
7.1	Local offices have climate change governance rules and regulations in place					
7.2	I am aware of the laws, regulations, and proclamations related to climate change protection					
7.3	Local community regulations are aligned with national climate change protection laws					
7.3	Climate change protection rules and regulations are easy to implement					
7.4	Climate change protection regulations are implemented effectively					
7.5	There is active participation of key actors in implementing climate change protection regulations					
7.6	Violations of climate change laws are punished according to legal provisions					

Part III: Institutional Constraints to Effective Urban Climate Governance

No.	Factors					
1.	**Policies and Regulatory Frameworks**	**1**	**2**	**3**	**4**	**5**
1.1	Absence of comprehensive climate policies at the local level					
1.2	Weak enforcement and compliance mechanisms for existing regulations					
1.3	Lack of policy integration between national, regional, and local levels					
1.4	Absence of climate adaptation and mitigation strategies tailored to local contexts					
1.5	Inadequate monitoring and evaluation frameworks for climate governance implementation					
1.6	Limited public participation in climate-related decision-making processes					
1.7	Ambiguity in institutional roles and responsibilities in climate governance					
1.8	Local government authority constraints over key climate-related policies					
2.	**Financing and Budget Allocation**	**1**	**2**	**3**	**4**	**5**
2.1	Lack of dedicated and sustainable funding sources for climate governance					
2.2	Insufficient financial resources for implementing climate adaptation and mitigation plans					
2.3	Inefficient allocation and utilization of climate-related budgets					
2.4	Dependency on external donors for climate action financing					
2.5	Limited financial incentives for private sector engagement in climate governance					
3.	**Human Resources and Institutional Capacity**					
3.1	Shortage of trained personnel in urban climate governance					
3.2	High turnover of skilled professionals in environmental governance offices					
3.3	Limited professional development and capacity-building programs for climate governance personnel					
3.4	Inadequate technical expertise to design and implement climate strategies					
4.	**Technology and Data Management**	**1**	**2**	**3**	**4**	**5**

4.1	Limited access to modern climate adaptation technologies					
4.2	Absence of digital platforms for climate data collection and monitoring					
4.3	Weak data-sharing mechanisms between government institutions					
4.4	Lack of early warning systems for climate-related disasters					
4.5	Inadequate research and development support for climate innovations					
5.	**Political Will and Commitment**	**1**	**2**	**3**	**4**	**5**
5.1	Lack of strong political commitment to climate action at local levels					
5.2	Frequent changes in government leadership affecting policy continuity					
5.3	Limited prioritization of climate governance in urban development plans					
5.4	Weak accountability mechanisms for climate policy implementation					
6.	**Information and Public Awareness**	**1**	**2**	**3**	**4**	**5**
6.1	Limited awareness and engagement of communities in climate governance					
6.2	Lack of transparency in climate governance decisions and actions					
6.3	Limited availability of localized climate data for decision-making					
6.4	Inadequate climate education and awareness programs for the public					
7.	**Institutional Coordination and Collaboration**	**1**	**2**	**3**	**4**	**5**
7.1	Weak coordination between different government agencies involved in climate governance					
7.2	Limited engagement of private sector and civil society in climate governance					
7.3	Absence of multi-stakeholder platforms for climate governance discussions					
7.4	Fragmented institutional mandates leading to overlapping responsibilities					
8.	**Regional Political Instability**	**1**	**2**	**3**	**4**	**5**
8.1	Impact of regional conflicts on climate governance initiatives					
8.2	Political instability affecting resource allocation for climate programs					
8.3	Disruptions in governance structures due to regional crises					

8.4	Limited international cooperation and support due to instability					

Appendix 1: Tool 2: Key Informant Interview (KII) Guide

This guide is designed to collect qualitative data from key stakeholders on institutional effectiveness and challenges in Urban Climate Governance. It is strictly confidential and will be used for research purposes only.

Part I: For Government Officials

1. What institutional mechanisms are in place to ensure accountability and transparency in climate governance planning and budgeting?
2. To what extent are national and regional climate policies effectively integrated into local governance frameworks?
3. How are communities, the private sector, and CSOs engaged in planning and implementing climate initiatives in Bahir Dar?
4. How would you assess the level of institutional capacity (staffing, skills, budget, and technical tools) to implement climate governance?
5. Are sufficient financial and technological resources available for monitoring, early warning systems, and project implementation?
6. How effective are existing platforms for inter-agency coordination on climate change governance?
7. How has regional political instability affected institutional performance or donor partnerships?
8. What is the level of political commitment among local leaders to drive effective climate action?

Part II: For Community Members

1. Have you or your community participated in any local climate planning or awareness programs? If so, what was your experience?
2. Do you feel local authorities are accountable when climate-related problems occur in your area?
3. How informed are you and your neighbors about climate risks such as flooding, drought, or extreme heat?

4. Have traditional or indigenous adaptation practices been considered in local climate actions?
5. Are there visible climate adaptation or mitigation projects implemented in your community?
6. In your opinion, what are the major challenges or gaps in government response to local climate needs?

Part III: For Private Sector Representatives

1. What is the nature of your organization's involvement in climate-related planning or implementation?
2. Are there existing incentives or policies (e.g., grants, tax breaks) that encourage your participation in climate action?
3. How do you assess the level of collaboration between your organization and government agencies on climate initiatives?
4. Is your organization included in platforms for multi-stakeholder dialogue on climate governance?
5. What resources, training, or information would improve your ability to contribute to climate adaptation or mitigation?
6. From your perspective, how effectively are climate laws and environmental standards enforced on private actors?

Part IV: For Civil Society Organization (CSO) Leaders

1. How do you monitor government transparency and accountability in the implementation of climate projects?
2. What challenges do you face in engaging communities, especially vulnerable groups, in climate actions?
3. Are there regular opportunities for CSOs to contribute to policy dialogue or co-design climate strategies?
4. Do you think the local government adequately supports and recognizes CSO contributions to climate governance?
5. What is your assessment of public awareness levels about climate change and adaptation strategies in Bahir Dar?
6. Have you observed disruptions in CSO-government cooperation due to regional instability or leadership transitions?

Appendix 1: Tool 3: Focus Group Discussion (FGD) Areas and Leading Questions

Part I: Perceptions of Climate Variability and Change

1. Have you observed changes in climate conditions (rainfall, temperature, droughts) over the past 20–30 years in your area? How have these changes affected your daily life?
2. What do you believe are the major causes of these climatic changes?
3. Do you think these changes are natural or influenced by human activity? Please explain.

Part II: Urban Expansion and Land Use Change

4. In your experience, how has urban expansion changed land use patterns in your community (e.g., farmland loss, construction, road expansion)?
5. What types of land use have changed most (e.g., cultivated land, forests, grazing lands)? Why do you think these changes happened?
6. Have you or others in your community lost access to farmland or experienced reduced productivity due to urban development?

Part III: Livelihood Impacts of Climate and Land Use Change

7. What major challenges has your household faced in recent years related to climate variability or urban growth?
8. Can you describe how these challenges have impacted your farming activities, food availability, or income?
9. Have you experienced any damage to assets, livestock loss, or crop failure due to droughts or floods?

Part IV: Coping and Adaptation Strategies

10. What measures have you taken to adapt to these changes (e.g., changing crops, using irrigation, off-farm work)?
11. Are there any traditional or community-level strategies used to deal with land and climate pressures?
12. What challenges or barriers make it hard for you to adapt?

Part V: Access to Information, Support, and Technology

13. How do you get information related to climate, farming, or early warnings (e.g., radio, extension agents, neighbours)?
14. Are extension services and agricultural experts helpful to you? How often do they visit or support you?

15. Do you receive any support (e.g., improved seeds, credit, training) from government or NGOs?

Part VI: Institutional and Governance Issues

16. How would you assess the role of local government or urban authorities in protecting farmland or supporting farmers?
17. Do you think there are fair policies or land use plans in place? Are farmers consulted when land is taken or changed?

Appendix 1: Tool 4: Structured Interview Questions for Peri-Urban Farmers

This structured interview is designed to collect quantitative data from peri-urban farmers residing in and around Bahir Dar City. The objective is to assess how urban expansion and climate variability are influencing household-level of livelihood vulnerability. The information gathered will be used solely for academic research at Bahir Dar University, Department of Geography and Environmental Studies. Your responses will remain confidential and will be used only for research purposes. Participation is entirely voluntary, and you may choose not to answer any question or to withdraw at any time.

Part I: **Background profile of the respondents**

1. Kebele / Village: _____
2. Sub-city: _____
3. Sex of household head : ☐ Male ☐ Female
4. Age of household head : _____ years
5. Marital status 1. Married 2. Single 3. Widowed 4. Divorced 5. Separated
6. Family size_____
7. Educational status of the household head 1. Illiterate 2. Elementary 3. Junior 4. Secondary School 5. Higher education
8. Monthly income _____

Part II: **Physical and socio economic data**

A. Social networks

1. Are you a member of any community-based organization (e.g., Idir, cooperative)?

   ☐ Yes ☐ No

2. Do you take part in traditional group work (e.g., Debo, Wenfel)? ☐ Yes ☐ No
3. Can you get help from neighbors or relatives during hard times? ☐ Yes ☐ No
4. On average, how many non-working days per month do you or your household members have? ____

B. Livelihood strategies

5. Is agriculture (crop and/or livestock) the main source of income for your household?
   ☐ Yes ☐ No
6. Do you or any household member participate in income-generating activities other than farming (e.g., petty trade, crafts, wage labor)? ☐ Yes ☐ No
7. Does your household rely on remittances or income from family members working in another area? ☐ Yes ☐ No
8. Do you practice irrigation farming on your land? ☐ Yes ☐ No
9. Have you used improved agricultural practices in the past year (e.g., crop rotation, drought-tolerant seeds, short-maturing crops)? ☐ Yes ☐ No
10. Do you keep more than one type of livestock (e.g., cattle, goats)? ☐ Yes ☐ No ☐ Not applicable
11. Do you have access to credit or loan services to support your farming or other livelihood activities? ☐ Yes ☐ No
12. Have you received any form of aid (e.g., food, farming inputs) from government or NGOs in the last 12 months? ☐ Yes ☐ No

C. Socio-demographic profile

13. Please fill in the number of household members in each age and gender category:

Age Group	Male	Female	Total
Under 15 years			
15–65 years			
Over 65 years			
Total			

14. How many household members (aged 6 or older) have attended school (any level)? _____ persons

15. What is the highest education level completed by any member of your household?
    ☐ No formal education ☐ Primary (Grades 1–8) ☐ Secondary (Grades 9–12)
    ☐ Vocational training ☐ College/University
16. How many adult household members (15 years and older) are unable to read and write?____ persons
17. How many members of your household are currently enrolled in school or university?_____ persons

D. Food

18. Does your household rely mainly on your own farm production for food consumption?
    ☐ Yes ☐ No
19. In the past 12 months, were there any months during which your family did not have enough food to meet your needs? ☐ Yes ☐ No
20. (If Yes to Q19) How many months in the last year did your household face food shortages?
    ☐ 1–2 months ☐ 3–5 months ☐ 6–9 months ☐ 10–12 months
21. Does your household preserve part of the harvested crops for use in the dry season?
    ☐ Yes ☐ No
22. Do you preserve seeds for planting in the next agricultural season? ☐ Yes ☐ No
23. How many different types of crops did your household grow in the last agricultural season?
    ☐ One crop only ☐ Two types ☐ Three or more types
24. Did your household receive any food assistance (from the government, NGOs, or others) in the last 12 months? ☐ Yes ☐ No
25. During times of food shortage, do you change the quantity or quality of food your household consumes (e.g., reduce meals, eat less preferred foods)? ☐ Yes ☐ No

E. LULC and sustainability

26. Do you or your household own farmland? ☐ Yes ☐ No
27. (If Yes to Q.26) What is the total size of your farmland (in hectares)? Cultivated: _____, Grazing/Woodland: ____, Irrigated: ____, Other (specify): _____, Total: ____ hectares
28. Has the size of your farmland changed since you started farming?
    ☐ Increased ☐ Decreased ☐ No change

29. If your land size has decreased, what is the main reason? ☐ Land taken for urban development ☐ Shared with children ☐ Land degradation or abandonment ☐ Flooding or water encroachment ☐ Other (please specify): _____

30. Over the last 5–10 years, how has your average crop productivity (yield per hectare) changed? ☐ Increased ☐ Decreased ☐ No change

31. What do you think are the main reasons for the change in crop productivity? ☐ Improved inputs or practices ☐ Rainfall variability or drought ☐ Land degradation ☐ Pests/diseases ☐ Other: _____

32. Have you observed major land use or land cover changes in your locality since 1994 (e.g., farmland turned into buildings, roads, or settlements)? ☐ Yes ☐ No

33. Which type of land use has shown the most rapid change in your area? ☐ Cultivated land ☐ Forest and woodland ☐ Grazing land ☐ Wetlands ☐ Other: _____

34. What are the major causes of land use/land cover change in your locality? ☐ Urban expansion ☐ Population growth ☐ Infrastructure development ☐ Climate variability ☐ Other: _____

F. Water

35. Does your household have regular access to a safe and reliable source of drinking water? ☐ Yes ☐ No

36. How far (in minutes) does it usually take to collect water for household use (round trip)? ☐ Less than 15 minutes ☐ 15–30 minutes ☐ 31–60 minutes ☐ More than 1 hour

37. Do you rely on natural water sources (e.g., river, spring, lake) for drinking or domestic use? ☐ Yes ☐ No

38. Do you use irrigation water for crop production? ☐ Yes ☐ No

39. (If Yes to Q40) Is the irrigation water shared with other users in a rotational system (e.g., shifts)? ☐ Yes ☐ No

F. Infrastructure

40. How long does it take (on foot) to reach the nearest all-weather road from your home? Less than 30 minutes ☐ 30 minutes to 1 hour ☐ 1–2 hours ☐ More than 2 hours

41. How long does it take to reach the nearest health service center (clinic or hospital)?

☐ Less than 30 minutes ☐ 30 minutes to 1 hour ☐ 1–2 hours ☐ More than 2 hours

42. How long does it take to reach the nearest primary or secondary school from your home?

☐ Less than 30 minutes ☐ 30 minutes to 1 hour ☐ 1–2 hours ☐ More than 2 hours

43. Do you currently send your children to school? ☐ Yes ☐ No ☐ Not applicable (no school-age children)

44. How far is the nearest market where you sell or buy agricultural or household products?

☐ Less than 5 km ☐ 5–10 km ☐ 10–20 km ☐ More than 20 km

45. Do you have access to electricity at your home? ☐ Yes ☐ No

46. Do you have access to mobile phone or telephone services? ☐ Yes ☐ No

G. Climate variability and hazards

47. Compared to 30 years ago, has the climate in your area changed significantly? ☐ Yes ☐ No ☐ Not sure

48. What change have you observed in temperature over the past 30 years?

☐ Increase ☐ Decrease ☐ No change ☐ Don't know

49. What change have you observed in rainfall patterns over the past 30 years?

☐ Increase in rainfall ☐ Decrease in rainfall☐ Shift in rainfall season ☐ Increase in drought frequency ☐ No change ☐ Don't know

50. How many major drought events has your locality experienced in the past 30 years?

☐ None ☐ 1–2 times ☐ 3–5 times ☐ More than 5 times

51. How many major flood events has your locality experienced in the past 30 years?

☐ None ☐ 1–2 times ☐ 3–5 times ☐ More than 5 times

52. Has your household ever incurred losses due to climate-related events (e.g., floods, droughts, storms)? ☐ Yes ☐ No

53. What impacts of climate change have you experienced in your agricultural activities?

☐ Changes in planting/harvest seasons ☐ Changes in crop types ☐ Decline in crop yield ☐None of the above ☐Other (specify): _____

54. Have you ever received any early warning or advance notice before a flood or drought event? ☐ Yes ☐ No

H.Technology

55. Do you use any of the following agricultural inputs in your farming? (Select all that apply)

☐ Fertilizer (organic or chemical) ☐ Improved seeds ☐ Pesticides or insecticides

☐ None of the above

56. Is the supply of these inputs (fertilizer, seed, pesticides) timely and sufficient in your area?

☐ Yes ☐ No

57. Do you receive agricultural extension services in your locality? ☐Yes ☐No. How often?

58. Do you have regular access to climate-related information (e.g., weather forecasts, drought warnings)? ☐ Yes ☐ No

59. What is your main source of climate information? (Select one) ☐ Radio ☐ Television

☐ Extension agents ☐ Neighbors/friends ☐ Social media ☐Other: _____

Appendix 2

List of Publications, Seminar and conference

The lists of published articles, and publishable manuscript under review for this dissertation are listed below.

A. Published Article From the Dissertation

1. Melese, M., Anteneh, M., & Bantigegn, S. (2025). Urbanization and land surface temperature dynamics in Bahir Dar, Ethiopia: a comparative analysis of pre- and post-capital status. *Frontiers in Environmental Science*, April, 1–18. https://doi.org/10.3389/fenvs.2025.1569636
2. Melese, M., Anteneh, M., & Bantigegn, S. (2026). Evaluating institutional effectiveness in urban climate governance: The case of Bahir Dar City, Northwestern Ethiopia. *City and Environment Interactions*, 29(20), 100316. https://doi.org/10.1016/j.cacint.2026.100316

3. Melese, M., Anteneh, M., & Bantigegn, S. (2026). Institutional constraints on effective urban climate governance in Bahir Dar City, Ethiopia. *Discover Sustainability, 7(325)*. https://doi.org/10.1007/S43621-026-02655-6

4. Melese, M., Anteneh, M., & Bantigegn, S. (2026). Assessing Livelihood Vulnerability of Peri-Urban Farmers to Urban Expansion and Climate Variability in Bahir Dar, Ethiopia. *Geo: Geography and Environment*, Wiley, 13(1). https://doi.org/10.1002/geo2.70096

B. Published Article During Course work

5. Melese, M., Assefa, Y., & Meselu, Y. (2025). Determinants of household-level solid waste sorting practice the case of Bure town, North-western Ethiopia. *Cogent Social Sciences*, 11(1), 2483388. https://doi.org/10.1080/23311886.2025.2483388

C. Seminar and conference presentations

- **Friday seminar** presentations at Bahir Dar University, Faculty of Social sciences on December, 2025. https://drive.google.com/file/d/1zg7jv4Y4Yg0bweeF8RDrlSwy0nMi5zbj/view?usp=drive_link
- National conference presentation at the **5th African Graduate Students Conference**, Bahir Dar University, on 12-13 May 2025. https://drive.google.com/file/d/14d53j7rE4IOJJZ8RsUxlIxAuYQSgB-uC/view?usp=drive_link
- International conference presentation at the **2nd International Space and Geospatial Sciences** Annual Research Conference, Space Science and Geospatial Institute, on 26-27 June 2025. https://drive.google.com/file/d/1_saHEZqlT1Nsya3KzfTZpLdTdHYTNH8O/view?usp=drive_link