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Evaluating Urban Green Infrastructure Connectivity and Microclimate Perceptions: Lessons Learned from Piassa Corridor Development, Addis Ababa

By: Alazar Berhanu

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Evaluating Urban Green Infrastructure Connectivity and Microclimate Perceptions: Lessons Learned from Piassa Corridor Development, Addis Ababa

A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Infrastructure Planning and Management

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DECLARATION

I hereby declare that this thesis entitled "Evaluating Urban Green Infrastructure Connectivity and Microclimate Perceptions: Lessons Learned from Piassa Corridor Development, Addis Ababa" is a product of my original research work, and it has not been submitted to any other university for any academic degree. Materials and information other than my own are dually acknowledged.

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LETTER OF CERTIFICATION

I hereby certify that I have read the revised version of the thesis entitled "Evaluating Urban Green Infrastructure Connectivity and Microclimate Perceptions: Lessons Learned from Piassa Corridor Development, Addis Ababa" prepared under my guidance by **Alazar Berhanu** submitted in partial fulfillment of the requirements for the degree of Master of Science in Infrastructure Planning and Management. Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

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Abstract

Rapid urbanization and road corridor development in Addis Ababa present a critical challenge to the spatial integrity, microclimate, connectivity, and sustainability of the city's Urban Green Infrastructure (UGI). This study evaluates the impact of road corridor expansion on UGI in the historical Piassa area of Addis Ababa between 2015 and 2026, using a sequential mixed-methods design that integrates multi-temporal satellite Land Use/Land Cover (LULC) classification and FRAGSTATS landscape metrics with a structured survey of 60 local stakeholders and institutional Key Informant Interviews (KIIs). Within the 180-hectare study area, total vegetated cover increased by 158.9%, from 15.1 to 39.0 hectares, driven primarily by formalization of the Kechene river corridor into Arada Park. This consolidation reduced the landscape Splitting Index (SPLIT) by 92%, from a severely fragmented baseline of 182 to a corridor-anchored value of 14, while landscape cohesion rose from 34 to 82. However, these structural gains coexist with a planning paradox: persistent micro-level functional and environmental deficits along active transit axes. Survey findings show 65% of respondents perceive the area as warmer since redevelopment, 60% report inadequate pedestrian shade, and 70% observe that corridor design prioritizes vehicular traffic over ecological and public-space functions. Key informant interviews trace this gap to a systemic policy-practice disconnect, where Environmental and Social Impact Assessments (ESIAs) are prepared only after road geometries are fixed, resulting in removal of mature indigenous trees and their replacement with narrow-canopied ornamental species. The study concludes that expanding structural green cover does not automatically guarantee ecological performance or pedestrian comfort without integrated governance. It recommends sequencing ecological design before road geometry is finalized, embedding canopy continuity targets into design briefs, establishing formal pre-design public consultations, and instituting a 3:1 compensatory green-space replacement ratio for mature trees removed during construction.

Keywords: Urban Green Infrastructure; Landscape Fragmentation; LULC; FRAGSTATS; Road Corridor Development; Microclimate Perception; Mixed-Methods; Piassa; Addis Ababa; Green Space Governance

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Abbreviations

AREA_CV	Patch Size Coefficient of Variation
AREA_MN	Mean Patch Size
AREA_SD	Patch Size Standard Deviation
CA	Total Class Area
CIRCLE_MN	Related Circumscribing Circle Mean
CLUMPY	Clumpiness Index
CONTAG	Contagion Index
CONTIG_MN	Contiguity Index Mean
DIVISION	Landscape Division Index
ED	Edge Density
ENN	Euclidean Nearest-Neighbor Distance
ENN_MN	Euclidean Nearest-Neighbor Distance Mean
ENN_SD	Euclidean Nearest-Neighbor Distance Standard Deviation
FRAGSTATS	Spatial Pattern Analysis Program for Quantifying Landscape Structure
GI	Green Infrastructure
IJI	Interspersion and Juxtaposition Index
LPI	Largest Patch Index
MESH	Effective Mesh Size
NDVI	Normalized Difference Vegetation Index
NP	Number of Patches
PAFRAC	Perimeter-Area Fractal Dimension
PARA_MN	Perimeter-Area Ratio Mean
PD	Patch Density
PLAND	Percentage of Landscape
PROX_MN	Proximity Index Mean
PR	Patch Richness
SHAPE_MN	Mean Shape Index
SHDI	Shannon's Diversity Index
SHEI	Shannon's Evenness Index
SPLIT	Splitting Index
TE	Total Edge
UGI	Urban Green Infrastructure
DOS	Dark Object Subtraction
GEE	Google Earth Engine
GPS	Global Positioning System
LULC	Land Use / Land Cover
MLC	Maximum Likelihood Classification
NIR	Near-Infrared
OA	Overall Accuracy
OLS	Ordinary Least Squares
PCC	Post-Classification Comparison
RMSE	Root Mean Square Error
RS	Remote Sensing
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
AACRA	Addis Ababa City Roads Authority
EEC	Ethiopian Engineering Corporation
ESIA	Environmental and Social Impact Assessment
KII	Key Informant Interview

1. Chapter One: Introduction

1.1 Background of the Study

The twenty-first century is increasingly defined by its urban character, with more than half of the global population now residing in cities (Worku, 2020). While urban centers serve as primary engines of economic development, rapid urbanization in the Global South often leads to environmental degradation and the fragmentation of public spaces (Taiwo & Green, 2024). In Addis Ababa, this tension is currently exemplified by intensive road corridor development, where the expansion of 'grey' infrastructure frequently compromises the spatial integrity of the city's Urban Green Infrastructure (UGI). As a strategically planned network of natural areas including parks, forests, and wetlands UGI functions as a critical framework for urban sustainability. However, the rapid conversion of land for transit networks threatens to decouple these essential green systems from the built environment (Ugochukwu Kanayo Ashinze, 2024). This study, therefore, examines the impact of such infrastructure projects on UGI to ensure that urban growth does not undermine the ecological resilience and human well-being of the capital (Abdeta, 2025).

Sub-Saharan Africa is undergoing a profound rural-to-urban transformation, with Ethiopia's capital, Addis Ababa, emerging as one of the region's most rapidly expanding metropolitan centers (Agona & Abebe, 2024). Current population estimates for the 2026 metro area reach approximately 6.2 million, a figure that significantly exceeds previous projections. This growth trajectory is driven by a high rate of natural increase alongside sustained rural-to-urban migration (World Urbanization Prospects: The 2024 Revision, 2024). Research indicates that these demographic shifts are motivated by diverse 'push' and 'pull' factors, ranging from economic aspirations to displacement caused by environmental degradation and regional instability (Sahle, 2025). Spatially, this expansion manifests through two primary patterns: the intensive densification of the historical urban core and extensive horizontal sprawl into peripheral agricultural lands, resulting in the rapid conversion of rural landscapes into urbanized land use (Agona & Abebe, 2024).

Beyond their role in modernization, road corridor developments serve as the primary spatial units of intervention for this study. While these projects function as strategic axes for connectivity and ‘smart city’ branding, they act as catalysts for intensive land take and surface sealing, where previously permeable soils are converted into impervious asphalt and concrete (Sahle, 2025). This transformation frequently necessitates the removal of established street trees and the encroachment upon residual green buffers, resulting in acute ecological fragmentation within the urban fabric (Wubengda, 2021). Consequently, these corridors represent a ‘contested landscape’: they are simultaneous sources of environmental stress through increased runoff and urban heat and critical platforms for integrating Nature-Based Solutions (NBS), such as bio-swales and integrated street canopies. Analytically, these corridors provide the specific geographic lens required to measure the tension between gray infrastructure expansion and the preservation of Urban Green Infrastructure (UGI) spatial integrity (Wubengda, 2021).

Green infrastructure is essential for the sustainability and habitability of Addis Ababa. As an environment-friendly system, UGI provides regulating services such as urban temperature regulation, air filtrations, and carbon sequestration (Feyisa, 2022). It also plays a key role in flood protection, where wetlands and porous surfaces absorb heavy seasonal rainfall (Meshesha, 2025). GI also fosters social cohesion and community trust by serving as communal hubs for interaction among various residents. Culturally, these spaces preserve local identity and heritage by protecting landmarks and traditional gathering sites. Finally, well-maintained GI supports economic prosperity by increasing land values and generating employment in landscaping and tourism (Herodowicz, 2021). Without active solutions, the city confronts a future of worsening microclimates, intensifying flooding, and a "grey escalation" that renders urban neighborhoods unlivable (Gelan & Girma, 2021a).

The road corridor development program in Addis Ababa exists as a central element of a wider national vision for resilient urban restoration and smart city transformation (Sahle et al., 2025). This initiative, which the Addis Ababa City Road Authority (AACRA) manages, operates to restore, upgrading, and develop the city’s aging infrastructure while modernizing key tourism hubs (Sahle, 2025). A primary example of this initiative is the African Avenue (Bole Road) project, which planners classify as a ‘VIP street’ to project a modernized city image to international public figures who enter from the airport (Wubengda, 2021).

The intentions of these corridor developments are multidimensional, highlighting both functionality and urban aesthetics. First and foremost, the projects aim to improve mobility, ease traffic congestion, and advance pedestrian infrastructure (Sahle, 2025). A serious safety objective is to reduce traffic collisions, which constitute a severe challenge for the city (Wubengda, 2021). Furthermore, the program seeks to recover urban livability and social unity by providing high-quality public spaces, seating areas, and architectural icons (Sahle, 2025). From an environmental perspective, the objectives include integrating Nature-Based Solutions (NBS) such as bio-swales, landscaped medians, and street trees to mitigate the Urban Heat Accumulation (UHA) effect, manage storm water runoff, and improve air quality (Sahle, 2025).

In terms of progress, the first phase of development covers approximately 40 kilometers across seven strategic routes that connect major urban centers like Adwa Victory Memorial Square-Arat Kilo-Kebena-Kenya Embassy-Megenagna, Megenagna-Gurde Shola-Salite Mehirete Church-Civil Service-Altad Michael Church-CMC-Semit Pepsi, Bole Airport, and Mexico Square-Sar Bete-Carl Square, Arat Kilo-National Palace-Estifanose Church-Bole Road-Wollo Sefer, Adwa Victory Memorial Square-Churchill Avenune-Mexico-Legehare-Stadium-Meskile Square, Arat Kilo, Sidest Kilo, and Shiro Meda- Kuskuam Entoto-Botanic Garden Roads (Sahle, 2025). The second phase follows roughly the same blueprint but adds an additional 132 kilometers of improved corridors.

The program implements ‘complete street’ designs containing wider sidewalks and cycling lanes to better assist the 70% of the population who are pedestrians (Wubengda, 2021). In spite of these advancements, scientific evaluations of the African Avenue corridor recognize a significant gap between its current ecological performance and its potential, as expand infrastructure often continues to prioritize vehicular flow over a fully integrated green network (Wubengda, 2021).

This study evaluates urban green infrastructure connectivity and microclimate perceptions in Addis Ababa. While existing literature acknowledges that UGI is often sidelined in favor of ‘grey’ infrastructure, there remains a critical research gap regarding the spatiotemporal dynamics of this trade-off. Specifically, it is not yet understood how the current phase of intensive corridor expansion (2024–2026) physically fragments the urban landscape, transforming continuous green belts into isolated, non-functional patches (Gebru, 2023). There is a lack of empirical evidence quantifying the degree of ecological disconnection and ‘barrier effects’ caused by these transit axes, which may permanently decouple the urban core from its remaining ecosystem services. This study addresses this gap by analyzing the threshold at which corridor-driven land-take compromises the connectivity and sustainability of the UGI network, providing a vital framework for integrating ecological safeguarding into Addis Ababa’s modernization agenda.

This study adopts a mixed-methods research (MMR) design to evaluate the complex intersection of infrastructure expansion and ecological integrity. By integrating spatiotemporal geospatial analysis specifically Land Use/Land Cover (LULC) change detection and landscape metrics with qualitative insights from semi-structured stakeholder interviews, the research identifies critical spatial ‘hotspots’ where road developments compromise the urban green fabric. The outcomes provide an evidence-based policy framework intended to align Addis Ababa’s corridor modernization with Sustainable Development Goal (SDG) 11, which advocates for inclusive, resilient, and sustainable cities (Yirga, 2022). Ultimately, this research seeks to bridge the systemic gap between transport policy and environmental practice, offering a roadmap for balancing high-density urban growth with ecological safeguarding in Ethiopia (Abdeta, 2025).

1.2 Statement of the Problem

The 21st century features a crucial move as the global population progressively settles toward urban centers, with Addis Ababa emerging as an important point for rapid rural-to-urban transformation (Agona & Abebe, 2024). While Addis Ababa’s rapid urbanization estimated at a metro population of 6.2 million in 2026 is an engine for economic innovation, its current spatial trajectory presents a critical planning paradox (World Urbanization Prospects: The 2024 Revision, 2024). The city is transitioning from its historical ‘critical urban green space network’ identity to an Urban Heat Accumulation (UHA), a shift driven by intensive road corridor development and the subsequent surface sealing of permeable landscapes. The core problem lies in the systemic decoupling of ‘grey’ infrastructure expansion from ecological safeguarding. Current transit corridors are frequently designed as isolated linear axes, functioning as physical barriers that fragment the broader Urban Green Infrastructure (UGI) network (Woldesemayat, 2021). This fragmentation transforms continuous ecological zones into isolated, non-functional patches, undermining the spatial integrity and climate resilience of the capital. Consequently, without an integrated framework that balances connectivity with green preservation, Addis Ababa's modernization risks permanently degrading the vital ecosystem services necessary for long-term urban sustainability (Mulatu, 2025).

Urban Green Infrastructure (UGI) a strategically planned network of natural and semi-natural areas, is vital for alleviating these environmental costs by providing essential regulating services such as storm water management, air purification, and urban cooling (Cheshmehzangi, 2021). However, the spatial integrity of Addis Ababa's UGI is under severe threat from high-density densification. Recent spatial configuration analyses indicate a high degree of fragmentation, where 86.2% of individual green patches measure less than 3,000 m^2 (MDPI, 2021). This degradation directly compromises human well-being, as current recreational park per capita is estimated at only 0.37–0.52 m^2a figure significantly lower than the World Health Organization (WHO) minimum of 9 m^2 and the Ethiopian National Urban Green Infrastructure Standard of 15 m^2 (Ministry of Urban Development and Housing [MUDHo], 2015). If this spatial destruction continues unchecked, the city confronts a future of increased flooding, deteriorating microclimates, and diminished social cohesion, as green spaces function as vital 'communal hubs' that support mental health and community expectation (Gebru, 2023).

Central to the city's modernization is the recent prioritization of road corridor developments which serve as strategic axes for connectivity and 'smart city' transformation (Sahle, 2025). While these initiatives aim to implement 'complete street' designs incorporating broader sidewalks and cycling lanes they frequently exist in a state of spatial and functional conflict with existing ecological networks (Wubengda, 2021). Evidence suggests a significant disparity between the current and potential green infrastructure benefits of these corridors, as transport planning often prioritizes vehicular mobility and urban aesthetics over the preservation of ecosystem services (Wubengda, 2021). Furthermore, the lack of inter-agency coordination leads to a form of 'negotiated planning,' where the immediate requirements of infrastructure expansion consistently override long-term environmental protection mandates (Mulatu, 2025).

The fundamental challenge stems from a persistent policy-practice gap, where urban green spaces are frequently relegated to 'residual' or 'leftover' status in infrastructure planning (Mulatu, 2025). While macro-level land-use trends in Ethiopia are well-documented, there is a distinct scarcity of research that quantifies the micro-level spatial effects of specific road corridor geometries on the connectivity and patch dynamics of the urban green network (Azagew & Worku, 2020). Specifically, the literature has yet to provide an empirical assessment of the 'barrier effect' the degree to which intensive corridor expansion physically severs ecological corridors and increases patch isolation (Woldesemayat & Genovese, 2021). This study addresses this gap by employing Landscape Metrics and Spatiotemporal Change Detection to scientifically measure the trade-offs between linear infrastructure growth and the spatial integrity of Urban Green Infrastructure (UGI). By moving beyond descriptive governance challenges, this research proposes an evidence-based framework that operationalizes ecological requirements into the corridor design process, ensuring that Addis Ababa's modernization does not compromise its long-term climate resilience (Moisa, 2023).

The tension between infrastructure growth and ecological preservation is best understood through the lens of systemic urban resilience. When the expansion of linear transport networks is characterized by extensive surface sealing replacing permeable landscapes with impervious concrete the city's inherent capacity for microclimate regulation and storm water attenuation is severely compromised. Without the strategic integration of functional green buffers, this uncontrolled expansion of 'grey' infrastructure leads to hydrological instability and an intensified Urban Heat Accumulation (UHA) effect. Consequently, the urban environment loses its ability to absorb environmental shocks, resulting in a state where rapid physical growth directly undermines the ecological viability and long-term habitability of the city.

The implications of these problems are severe and complex, threatening the current and future habitability of the city. As the spatial destruction of green infrastructure continues unchecked, Addis Ababa confronts deteriorating microclimates and rising flood risks due to the loss of porous surfaces that serve as a sponge for environmental shocks. The degradation of these green spaces also results in reduced social cohesion and mental health support, as they function as vital 'communal hubs' for the population. This study demonstrates these implications through a biological metaphor; when the road network expands by hardening every path into concrete without protective the green infrastructure; the 'urban environmental quality' deteriorates and sinks under the weight of its own growth. Ultimately, this 'grey escalation' risk rendering urban neighborhoods unlivable.

1.3 Objectives of the Study

1.3.1 General Objective

To assess the impact of road corridor development on urban green infrastructure in the Piassa area of Addis Ababa.

1.3.2 Specific Objectives

1. To evaluate the current spatial configuration, structural connectivity, and microclimate perceptions of Urban Green Infrastructure (UGI) within the Piassa district.

2. To quantify the longitudinal impact of road corridor expansion on the continuity and fragmentation of the UGI network.

3. To examine the institutional and design factors influencing UGI sustainability and propose integrated 'complete street' strategies for future expansion.

1.4 Research Questions

1 What are the current spatial structure, connectivity, and microclimate perceptions of urban green infrastructure in Piassa district?
2 How has road corridor development affected the continuity and network integrity of urban green infrastructure in the Piassa district?
3 What planning and design strategies can improve the sustainability and integration of urban green infrastructure under future road corridor expansion?

1.5 Scope of the Study

1.5.1 Spatial Scope

This study is geographically confined to the Piassa area of Addis Ababa and adopts it as a case study site for assessing the effects of road corridor development on urban green infrastructure. While the study is situated within the broader urban context of Addis Ababa, the detailed investigation does not cover the city. Instead, the analysis focuses specifically on the selected corridor segments and surrounding green infrastructure elements within Piassa. Therefore, the findings of the study should be understood as case-based insights derived from Piassa, with broader relevance to Addis Ababa only in a contextual and interpretive sense.

1.5.2 Thematic Scope

The thematic focus of this research is situated at the intersection of urban morphology, landscape ecology, and infrastructure planning, specifically evaluating the impact of road corridor development on the spatial integrity and sustainability of Urban Green Infrastructure (UGI). The study examines the physical and functional relationship between the expanding footprint of linear transport infrastructure and the structural connectivity of the city's green network. While the research incorporates a critical review of urban governance and planning policies through expert and professional perspectives, it is explicitly delimited from performing primary biological inventories, such as floral species diversity, tree health assessments, or soil chemistry analysis. Furthermore, the research prioritizes the spatial-physical interactions between infrastructure and ecology; consequently, it does not encompass broad socio-economic surveys of the public or econometric valuations of ecosystem services. Finally, while environmental degradation and climate resilience are central to the problem statement, the study does not provide primary meteorological modeling or localized air quality monitoring, focusing instead on the spatiotemporal transitions of Land Use/Land Cover (LULC) as a proxy for ecological health.

1.5.3 Temporal Scope

The temporal scope of this research spans an 11-year period from 2015 to 2026, a timeframe specifically selected to capture the most intensive era of infrastructure-led transformation in Addis Ababa's history. The baseline year of 2015 corresponds with the launch of the first Growth and Transformation Plan (GTP I), which catalyzed the large-scale expansion of the city's primary road network and the formalization of the Ring Road system. This period marks the critical transition from historical 'green-centric' urban patterns toward the current 'grey-centric' infrastructure model. The endpoint of 2026 is chosen to encompass the completion of the inaugural phase of the 2024–2026 Corridor Development Projects, allowing the study to evaluate the immediate spatial impacts of 'Smart City' street designs on the city's remaining ecological patches.

1.6 Significance of the Study

1.6.1 Significance to the city Administration

The practical significance of this research lies in its potential to provide the Addis Ababa City Administration specifically the Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau with a coordinated empirical baseline for integrated infrastructure planning. By quantifying the spatial trade-offs between road expansion and UGI integrity, the study offers a diagnostic framework that can assist transport engineers and urban planners in moving beyond mutually exclusive development models.

Furthermore, the research contributes to the local operationalization of Sustainable Development Goal 11 (SDG 11) by providing site-specific data that links linear infrastructure growth to ecological functionality. The findings are intended to serve as a technical resource for the refinement of "complete street" guidelines and environmentally sensitive design standards. Ultimately, this study supports the transition toward an integrated design approach where road networks are evaluated not only for vehicular efficiency but also for their role in maintaining the city’s broader ecological resilience and spatial continuity.

1.6.2 Significance to Policy Makers

For policymakers, the significance of this study lies in its capacity to address the implementation gap within the Ethiopian urban planning framework, particularly where infrastructure-led development may conflict with established ecological mandates. By providing an empirical basis for the evaluation of ‘negotiated planning’ outcomes, the research offers the necessary data to support the formulation and enforcement of more robust regulatory instruments, such as green corridor protection bylaws and compensatory green space policies. Furthermore, this research contributes to the shifting discourse on Urban Green Infrastructure (UGI) by reclassifying these areas from aesthetic amenities to critical urban infrastructure essential for public health, climate adaptation, and social equity. By providing a technical justification for the preservation of residual urban spaces, the study equips policymakers with a framework to manage the inherent tensions between rapid modernization and long-term urban livability. Ultimately, the findings provide a localized evidence base that can inform sustainable urban transformation strategies, positioning Addis Ababa's development trajectory within the broader context of resilient African urbanization.

1.6.3 Significance to the Scientific Community

This research contributes to the field of urban studies by providing a corridor-scale geospatial analysis that transitions beyond macro-level land-use trends to evaluate the micro-spatial dynamics of infrastructure development. By applying specific landscape ecology metrics such as Mean Patch Size and the Connectivity Index to the unique morphological context of Addis Ababa, the study demonstrates a replicable framework for measuring habitat fragmentation in rapidly urbanizing environments of the Global South. Furthermore, the study offers a methodological integration of quantitative spatial data and qualitative governance perspectives, providing a multi-dimensional understanding of the trade-offs between linear infrastructure growth and ecological sustainability. This mixed-methods approach facilitates a more nuanced analysis of how institutional decision-making directly influences spatial patterns of environmental degradation. Consequently, this research serves as localized evidence base and a technical reference for future longitudinal studies exploring the intersection of road ecology and urban resilient planning in high-density, developing urban centers.

1.7 Organization of the Study

This study is structured into five interconnected chapters that provide a systematic evaluation of how road corridor development impacts Urban Green Infrastructure (UGI) in Addis Ababa. Chapter one establishes the research foundations by defining the 'morpho-functional struggle' between urbanization and ecology, outlining the problem statement, and setting the spatiotemporal boundaries of the study within the Piassa district (2015–2026). Chapter Two develops the theoretical and conceptual framework by evaluating global principles of UGI, Nature-Based Solutions (NBS), and 'Complete Street' design while examining the 'policy-practice gap' that contextualizes ecological degradation in rapidly urbanizing regions. Chapter Three details the mixed-methods research design, describing the integration of quantitative geospatial analysis using landscape ecology metrics with qualitative stakeholder interviews to measure the longitudinal impact of infrastructure on the city's green network. Chapter Four presents empirical findings, mapping spatiotemporal transitions and analyzing the degree of fragmentation to identify the specific institutional and physical drivers of ecological loss. Finally, Chapter Five synthesizes these findings to provide a definitive assessment of road-corridor impacts and proposes actionable policy frameworks and design guidelines to foster synergy between future infrastructure projects and the restoration of Addis Ababa's ecological health.

2. Chapter Two: Literature Review

2.1 Introduction to the Literature Review

The twenty-first century marks a crucial shift in human settlement patterns, with more than half of the global population now living in cities. Although urban centers act as devices for economic growth and innovation, quick and often random urbanization in the Global South significantly destroys local environments, leading to the loss of natural ecosystems and the destruction of public spaces. In reaction to these challenges, Urban Green Infrastructure (UGI) has begun as a critical multifunctional strategy designed to provide essential ecosystem services that resolve urban expansion with environmental health (D. Wang, 2024).

Scholars explain UGI as a strategically planned network of natural and semi-natural areas as well as parks, urban forests, wetlands, and green corridors planned to improve urban resilience and human welfare (Taiwo & Green, 2024). Actual UGI depend on core principles of connectivity, multi-functionality, and multi-scale planning to safeguard that these natural elements function as a clear ecological system rather than isolated islands (Ayele, 2022). Urban Green Infrastructure (UGI) purposes as a vibrant tool to progress water preservation and permeability in heavily populated areas, ease the effect of the urban heat accumulation, and improve human well-being and biodiversity. The interdependence between healthy living environments and human wellness becomes specious through the ability of urban green spaces to enhancement social capital. Green Infrastructure (GI) comprises semi- natural structures specifically crafted to enhance the quality of life in urban settings (Miakhel, 2024).

“Green spaces” are described by the Environmental Protection Agency as ‘parks, community gardens, and cemeteries,’ with particular reference to ‘land that is partially or completely covered with grass, trees, shrubs, or other vegetation.’ (Nieuwenhuijsen, 2020). In this paper, ‘green infrastructure’ is defined as a system of multipurpose green areas throughout a designated area, providing benefits to both existing and new communities and supporting the creation of an excellent built and natural environment (Miakhel et al, 2024).

In many developed contexts, road and transport projects are progressively linked to green infrastructure and green corridors as tools to meet climate, health and SDG-11 goals. Systematic reviews of UGI show that in the Global North, GI research and execution are dominated by planning/policy, environmental and social functions, including cooling, storm-water management and recreation (Hanna, 2021). Green corridors are outlined as ecological pathways that link habitats, improve air and water quality, enable sustainable transport, and decrease urban heat accumulation while assistant inclusive, resilient cities (Fateen Nabilla Rasli, Mohammad Lui Juhari, 2025). Case studies such as greenways in Ma'anshan, China (a middle-income but institutionally 'developed' urban context) show that linear green infrastructure along transport routes can enhance livability and active travel even when tourism effects are modest (Zhang, 2020). Integrated approaches in some advanced cities also emphasize transit-oriented development, safe walking and cycling environments, and green buffers along corridors as core elements of sustainable urban form (Cervero, 2013).

In developing countries, road corridors are primarily promoted as engines of economic growth and regional integration, with environmental and green-infrastructure dimensions often secondary. A broad review of Sub-Saharan and South Asian transport infrastructure finds significant positive effects on growth, income, poverty reduction and employment, but also uneven distribution of benefits and trade-offs with environmental quality (Quium, 2019). For Indonesia's Trans-Java corridors, sustainability is understood in multiple dimensions, but public agencies still treat it largely through sectorial lenses; institutional and political constraints limit integrated environmental and social consideration in road planning (Suprayoga, 2020).

In China, though, there is emerging indication that transportation infrastructure and green-development agendas are being related panel data for 268 cities show that expansion of traffic infrastructure significantly develops urban green development efficiency when ecological defense is followed in parallel (Y. Wang & Li, 2022). More broadly across the Belt and Road Initiative (BRI), green-development valuations disclose spatial differences but an overall upward trend in green performance, with many participating countries looking for to reconcile growth with ecological limitations (Cuiyun & Chazhong, 2020). Green finance within BRI corridors, for example in the China Pakistan Economic Corridor, is found to backing sustainable infrastructure and green technology innovation, contributing to SDGs if maintained by strong governance

(Mahmood, 2021). At the same time, tourism and rapid urbanization along economic corridors can increase emissions unless renewable energy, ICT and regulatory measures are in place (Suprayoga, 2020).

Urban green and blue infrastructure research in the Global South shows a rapidly growing but uneven field Asia (especially China) dominates publications, while Africa and Latin America lag behind (Silvia, 2021). UGI is used to address greenery loss, food security and poverty, but is rarely implemented as systemic, low-impact infrastructure except in some Chinese 'Nature Based Solutions' for urban storm water management and greenway programs (Silvia, 2021). Methodological work from Costa Rica demonstrates that retrofitting multifunctional UGI along streets and public spaces can reduce runoff, add roadside greenery and improve social conditions in dense, infrastructure-poor areas (Fluhrer & Hack, 2020).

In African cities, such as Addis Ababa, recent urban-renewal projects have combined upgraded road corridors with flagship parks evaluation shows that social benefits (accessibility, recreation) are recognized, but ecological and cultural dimensions of green infrastructure need stronger emphasis and more inclusive planning (Sahle, 2025). Cairo illustrates a common challenge contemporary development favors 'grey' road expansion, with green corridors largely disappearing, leading to calls for an integrated gray–green corridor strategy based on international best practices. In Central Asia, work on Shymkent (Kazakhstan) highlights how mapping central and peripheral green 'cores' and linear natural/natural-artificial corridors can guide optimization of territory and support sustainable megacity development (Abduova, 2025).

For neighboring countries linked by economic and transport corridors, the Belt and Road Initiative provides a key example. Studies measuring green-development levels across BRI countries show strong spatial dependence and clustering of 'high–high' and 'low–low' performers, with differences driven largely by intra-regional disparities, especially in West Africa and the East Africa (Cuiyun & Chazhong, 2020). This suggests that neighboring states along the same corridor can influence each other's environmental performance, and that coordinated green standards and investments are important. Research on BRI and CPEC further indicates that when green finance, renewable energy and environmental regulations are integrated, economic corridors can support both community well-being and emissions reduction, though uncontrolled tourism and urbanization can still worsen pollution (Mahmood, 2021). More generally, reviews of UGI and GI stress that global knowledge and implementation are concentrated in a few regions (U.S., Europe, parts of China), with significant gaps in warmer regions and much of Asia, Africa and South America, highlighting the need for shared learning among neighboring developing countries on corridor-scale green strategies (Silvia, 2021).

In the precise context of Sub-Saharan Africa, Ethiopia practices one of the highest rates of rural-to-urban transformation on the continent (Gebreyesus, 2023). Its capital, Addis Ababa, serves as a primary example of this quick change, with a population expected to exceed 5 million by 2025 and 7.3 million by 2030 (Agona & Abebe, 2024). This development stems from high natural birth rates and thorough migration determined by rural environmental degradation, drought, and conflict (Gebreyesus, 2023). Substantially, this urbanization displays through persistent horizontal expansion into marginal farmlands and rigorous inner-city redevelopment directed at modernization (Agona & Abebe, 2024). Consequently, the city has transitioned from its historical 'critical urban green space network' identity to an Urban Heat Accumulation, suffering a devastating 32% loss of its green space over the last three decades (Wubengda, 2021). As built-up areas consume natural resources, the remaining green patches become highly fragmented; studies indicate that 86.2% of individual green patches in Addis Ababa now measure less than 3000 m^2 (Woldesemayat & Genovese, 2021).

Central to the city's modernization are road corridor developments, which serve as strategic axes for connectivity, economic growth, and 'smart city' transformation (Wubengda, 2021). Although these creativities implement 'complete street' plans with wider sidewalks and cycling lanes to accommodate the 70% of the population who are pedestrians, they regularly exist in a state of morpho-functional struggle with ecological networks (Sahle, 2025). The growth of these 'grey' infrastructures roads, buildings, and parking lots repeatedly happens at the cost of natural elements, increasing surface runoff and bargaining the capability of drainage systems (Gebreyesus, 2023). Peer-reviewed indication proposes a major gap between the current and potential green infrastructure welfares of these corridors, as transport planning often prioritizes vehicular mobility and aesthetics over the holistic integration of nature-based solutions (Wubengda, 2021).

The existence of strong green infrastructure remains vital for the sustainability and livability of Addis Ababa. Environmentally, UGI alleviates the Urban Heat Accumulation effect through shading and evapotranspiration, which efficiently lowers ambient temperatures (D. Wang, 2024). It plays a critical role in hydrological regulation, where features like wetlands and permeable surfaces absorb heavy seasonal rainfall to decrease the threat of pluvial flooding (Gebreyesus, 2023). Generally, access to public green spaces supports mental and physical health, adopts social cohesion, and preserves cultural heritage sites (Taiwo & Green, 2024). Though, a determined 'policy-practice gap' delays the effective integration of UGI in Ethiopia, as an engineer's regularly observe green spaces as 'wasteland' or 'leftover' areas rather than integral infrastructure (Debie & Mengistie, 2025).

This literature review evaluates urban green infrastructure connectivity and microclimate perceptions in Addis Ababa. It pursues to channel the division between high-level policy visions and site-scale execution by exploring how transport infrastructure contributes to habitat disintegration and the loss of vital ecosystem services (Gorgol, 2024). By creating global best practices and local realities, this review delivers a foundation for a new planning model that matches the city's circulatory needs (roads) with its ecological requirements (greenery) (Debie & Mengistie, 2025). Finally, this review highlights the urgency of caring urban nature to safeguard that rapidly growing cities remain resilient, comprehensive, and sustainable for future generations (Ugochukwu Kanayo Ashinze, 2024).

To conceptualize this challenge, think of green infrastructure as the 'critical urban green space network and Nature Based Solutions for urban storm water management' of the city, while the road network acts as its 'circulatory system.' If the circulatory system expands by hardening every vessel into concrete without preserving the space for the critical urban green space network to breathe or the Nature Based Solutions for urban storm water management to absorb environmental shocks, the entire urban environmental quality will eventually deteriorates and become increasingly vulnerable to flooding under the pressure of its own growth.

2.2 Conceptual Review

The conceptualization of Urban Green Infrastructure (UGI) has developed from viewing nature as an attractive service to recognizing it as an important, strategically planned network of natural and semi-natural areas (Herodowicz, 2021). Nothing like traditional 'green spaces' which frequently emphasis just on recreation, UGI exemplifies a multifunctional framework designed to be responsible for an extensive collection of ecosystem amenities including air and water purification, microclimate stabilization, and social well-being (Herodowicz, 2021). At its fundamental, UGI integrates 'blue' elements (rivers, wetlands, and ponds) with 'green' features (forests, parks, and street trees) to make a combined system that functions through all spatial scales from site-specific green roofs to city-regional ecological corridors (Cheshmehzangi, 2021). This agenda is increasingly known as a cost-effective and sustainable alternative to traditional 'grey' or engineered infrastructure, mainly in addressing 21st-century challenges like climate change and rapid urbanization (Herodowicz, 2021).

A vigorous theoretical framework for UGI is built upon numerous interlinked planning principles that confirm the network is more than the sum of its parts. The first principle is Multi-functionality, which commands that a single UGI component should deliver several welfares simultaneously (Korkou, 2023). For example, a green roof can defend a building from rainfall, decrease the Urban Heat Accumulation (UHA) consequence, advance insulation, and deliver a habitat for various species (Yirga, 2022). The second principle is Connectivity, which creates physical and functional relations between disjointed habitat (Isola, 2024). Interconnected green networks ease the movement of wildlife, preserve genetic diversity, and offer continuous pedestrian and cycling routes for residents(D. Wang, 2024).

The third principle is Multi-scale Planning, confirming that UGI purposes across different administrative and ecological limitations, from the neighborhood level to the national network (Yirga, 2022). The fourth principle, Integration (Green-Grey Synergy), encompasses the systematic combination of natural elements with the built environment, such as integrating bio-swales and street trees into road corridor developments to accomplish storm water (Mulatu, 2025). In conclusion, the attitude of Social Presence highlights that UGI must be designed through participatory procedures that symbolize the welfares of all stakeholders, including marginalized and underserved communities (Gelan & Girma, 2021).

The efficiency of UGI is frequently assessed through the RPCS framework, which classifies ecosystem services into four different domains. Modifiable Amenities are possibly the most serious for urban sustainability, surrounding climate regulation, air purification, and flood alleviation (Yirga, 2022). UGI decreases urban temperatures through protecting and evapotranspiration, and landscapes like permeable pavements and retention ponds catch rainfall to reduce the load on drainage systems (Czy, 2024). Provisioning facilities include the direct material outputs of nature, such as food making through urban agriculture, fresh water supply, and medicinal resources (D. Wang, 2024).

Cultural Services emphasis on the non-material welfares that advance the human condition, including recreational chances, aesthetic importance, and the protection of cultural heritage (Yirga, 2022). In cities like Addis Ababa, natural milestones like Epiphany help as vibrant hubs for spiritual practices and community uniqueness (Abdeta, 2025). Finally, Subsidiary Services deliver the foundational ecological developments necessary for all other amenities, such as soil health, nutrient cycling, and biodiversity conservation (D. Wang, 2024). Integrating these four domains into urban planning allows for the creation of a 'Nature-Based Solution' that arranges human and ecological health equally (Worku, 2020).

The presentation of UGI frameworks in the Global South necessitates a refinement thoughtful of exceptional socio-economic and political changing aspects. Numerous African cities knowledge 'false urbanization,' where rapid population growth overtakes economic development and recognized infrastructure establishment (Agona & Abebe, 2024). In cities like Addis Ababa, this has led to a 32% loss of green space over the last three decades, as built-up areas and informal settlements invade upon ecologically profound zones (Woldesemayat & Genovese, 2021). A persistent 'policy-practice gap' exists where green infrastructure is recognized in master plans but frequently treated as 'wasteland' or 'leftover space' during actual implementation (Mulatu, 2025).

Furthermore, the framework in the Global South must account for informality, which is often the 'normality' of urban life (Shackleton & Cilliers, 2022). Informal green spaces, such as riverbanks and road verges, often provide higher levels of indigenous biodiversity and essential provisioning services for the urban poor than formal parks (Mulatu, 2025). The conceptual framework must also prioritize Environmental Justice, addressing the inequitable distribution where low-income and marginalized neighborhoods are systematically underserved by high-quality UGI (Shackleton & Cilliers, 2022).

The governance of UGI involves managing the complex interactions between social and ecological components of the city (Pantaloni, 2022). Scholars contrast Mono-centric models (consolidated decision-making) with Polycentric models (distributed authority) (Mulatu, 2025). While polycentric governance is often theoretically preferred for its checks and balances, it can fail in cities like Addis Ababa if there is a lack of institutional coordination and administrative accountability (Mulatu, 2025). Effective governance requires multi-stakeholder platforms that include government agencies, NGOs, and community groups to co-manage natural assets (Abdeta, 2025).

To continue operative under changing conditions, UGI must implement an Adaptive Management approach (D. Wang, 2024). This repeated process encompasses planning, implementation, continuous monitoring, and adjustment based on response (D. Wang, 2024). For example, observing vegetation indices (OVI) and land surface temperatures permits planners to recognize ‘hotspots’ where UGI involvements are most necessary to advance urban thermal well-being (Moisa, 2023). This iterative approach safeguards that the infrastructure remains flexible and responsive to climate change uncertainties and developing societal needs (D. Wang, 2024).

Latest developments have integrated the Nature Futures Framework (NFF) into the urban dissertation to extend how we worth nature. This perception operationalizes three different viewpoints; Nature for Nature (NN), which emphases on biodiversity and ecological renovation with minimal human interference; Nature for Society (NS), which highlights nature's influences to human health and economic stability; and Nature as Culture (NC), which highlights the mystical and symbolic bonds between people and their environment (Sahle, 2025). In Addis Ababa, star projects like Unity Park, Andenet Park, Arada Plaza Park and the Friendship Park creativity are latest attempts to combine these perceptions by generating spaces that serve ecological, social, and cultural functions (Sahle, 2025).

In summary, in the conceptualization of this study, the independent variables consist of the core planning principles of Urban Green Infrastructure (UGI); multi-functionality, connectivity, multi-scale planning, and green-grey integration (synergy). These are further influenced by the Nature Futures Framework (NFF) perspectives, namely Nature for Nature, Nature for Society, and Nature as Culture. The dependent variables are the resulting ecosystem services that these frameworks produce, which include modifiable amenities such as climate and flood regulation, provisioning facilities like food and medicinal resources, cultural services including recreation and spiritual practices, and subsidiary services like biodiversity and soil health..

2.3 Empirical Review

The recent first phase of road corridor development in Addis Ababa incorporates roughly 40 kilometers across four key strategic paths (Sahle, 2025). The phase covers from Adwa Victory Memorial Square- Arat Kilo-Kebena-Kenya Embassy-Megenagna, Megenagna-Gurde Shola-Salite Mehirete Church-Civil Service-Altad Michael Church-CMC-Semit Pepsi, Bole Airport, and Mexico Square-Sar Bete-Carl Square, Arat Kilo-National Palace-Estifanose Church-Bole Road-Wollo Sefer, Adwa Victory Memorial Square-Churchill Avenune-Mexico-Legehare-Stadium-Meskile Square, Arat Kilo, Sidest Kilo, and Shiro Meda- Kuskuam Entoto-Botanic Garden Roads (Sahle, 2025). These courses smooth high volumes of vehicular and pedestrian traffic, helping as showcase corridors for the city’s broader urban renewal efforts (Sahle, 2025).

The extent of this expansion reflects a broader trend of urbanization that has increased the city's built-up area by 61% between 1986 and 2015 (Mulatu, 2025). This growth typically follows two patterns horizontal expansion into peripheral farmlands and intensive inner-city redevelopment (Herodowicz, 2021). Between 1986 and 2015, this relentless ‘grey extensification’ caused a 32% loss of green space (Rodríguez-gómez, 2025). In the outer zones of the city, urban areas increased by over 30% in each decade between 1989 and 2018, characterizing the aggressive frontiers of suburbanization (Woldesemayat, 2021).

Road corridors in Addis Ababa characterize more than ordinary well-designed paths; they attend as figurative entries that project a rationalized ‘smart city’ image to international visitors (Sahle, 2025). The African Avenue (Bole Road) project demonstrates this ‘VIP street’ position, acting as the primary appearance for foreign notables traveling from the international airport to the city center (Wubengda, 2021). Planners designed these corridors to advance the ‘look and feel’ of the city through aesthetically enhanced landscapes, seating areas, and architectural icons like the Adwa Victory Memorial (Sahle, 2025).

In spite of these aesthetic goals, the nature of these expansions tells a determined morpho-functional battle between grey infrastructure and the city's green network (Sahle, 2025). Though the ‘complete street’ manual endorses planting street trees to deliver shade and sequester carbon, transport planning frequently prioritizes vehicular mobility over the all-inclusive integration of nature-based explanations (Moisa, 2023). Research into African Avenue recognizes a major gap between the existing and possible green infrastructure welfares of the corridor, proposing that the existing design fails to influence its multifunctional potential (Wubengda, 2021).

A primary justification for the extensive spreading of road corridors is the decrease of traffic congestion and the improvement of road safety. Nevertheless, empirical indication proposes that spreading these roads has failed to decrease traffic crashes. In the case of African Avenue, police reports specify that the number of pedestrians exaggerated by accidents increased every month after the road was extended. Traffic officers perceive that broader roads often appeal more vehicle traffic and inspire higher speeds, which unexpectedly increases the occurrence and harshness of accidents (Wubengda, 2021).

Addis Ababa at present experiences a high degree of traffic accidents in spite of moderately low levels of car ownership. The city accounts for more than 60% of the traffic accidents in Ethiopia, with pedestrians suffering 79% of the total wounds (Wubengda, 2021). Professionals note that increased road width repeatedly discounts the security needs of pedestrians and the defensive role that green infrastructure, such as solid tree barriers, could play in calming traffic and defending non-motorized users from pollutant-heavy air (Ugochukwu Kanayo Ashinze, 2024).

The nature of road corridor development expressively encouragements the city’s hydrological cycle and microclimate (Chen, 2025). The replacement of vegetation with asphalt and concrete avoids rainfall from penetrating the soil, which intensely increases surface runoff and flood risks (Gebreyesus, 2023). Studies show that urbanization in such circumstances can raise annual surface runoff by up to 413% (Gebreyesus, 2023). Furthermore, the removal of vegetation along corridors contributes to the Urban Heat Accumulation (UHA) effect, where heat generated by traffic is accumulated in ‘urban canyons’ of concrete and glass (Cheshmehzangi, 2021).

Current green infrastructure along these corridors is repeatedly disjointed and underdeveloped (Woldesemayat & Genovese, 2021). Scientific analysis shows that 86.2% of specific green covers in Addis Ababa measure less than 3000 m^2, which relentlessly limits their ability to deliver cooling and habitat services (Woldesemayat, 2021). Although some new projects include bio-swales and tree planters for storm water management, these elements regularly exist in separation and lack the connectivity required to function as a comprehensible ecological system (Gebru, 2023). Accordingly, the city's per capita green space has dropped to between 0.37 and 0.52 m^2, deteriorating to meet the 15 m^2 national standard (Gebru, 2023).

The degree and nature of corridor developments are designed by a complex and regularly dysfunctional authority framework (Jacobsen, 2024). Responsibilities for road planning, land management and environmental fortification are divided among numerous agencies, such as the Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau. This disintegration leads to a ‘lack of coordination’ where a fresh built roads are sometimes demolished to install water or telecommunications lines (Jacobsen, 2024).

Additionally, a determined ‘policy-practice gap’ exists because planners regularly observe green spaces as ‘wasteland’ or ‘leftover areas’ that can be give up for more ‘economically productive’ road or housing projects. This lead to a state of ‘negotiated planning,’ where infrastructure main concern dependably take priority over environmental regulations (Jacobsen, 2024). Even when structural plans propose extensive green networks, these proposals are rarely implemented on the ground due to political interference and a lack of clear green space ordinances (Mulatu, 2025).

The expansion of major road corridors necessitated extensive land expropriations from peri-urban farmers and the relocation of residents from the inner city (Agona & Abebe, 2024). Over the past two decades, more than 6,431 farmer households were displaced by such projects, primarily for housing, investment, and infrastructure (Agona & Abebe, 2024). Many affected individuals report experiencing forced evictions without adequate consultation or fair compensation (Jacobsen, 2024). Beyond physical relocation, these projects contribute to ‘cultural displacement,’ as traditional gathering spaces and spiritual sites are often lost to the concrete expansion of the city's circulatory system (Sahle, 2025).

To alleviate these negative influences, specialists endorse that Addis Ababa ‘Urban Sprawl’ the auto-centric development tracks taken by Western cities (Wubengda, 2021). This involves shifting directly toward green transportation and not-motorized infrastructures (Wubengda, 2021). Integrating Nature-Based Solutions (NBS) such as permeable pavements and interconnected green corridors into road design can recover urban sustainability by allowing the city to ‘breathe’ and engage environmental shocks (D. Wang, 2024). Accomplishing this involves a fundamental shift in values, where green infrastructure is preserved as an important urban utility equal to roads and housing (Wubengda, 2021).

To understand this challenge, view the city’s road corridors as its ‘circulatory system’ and its green infrastructure as its ‘critical urban green space network and Nature Based Solutions for urban storm water management.’ If the circulatory system expands by hardening every vessel into concrete without leaving room for the critical urban green space network to filter the air or the Nature Based Solutions for urban storm water management to absorb the sudden shocks of a storm, the entire urban environmental quality will eventually deteriorates and urban area become increasingly vulnerable to flooding under the weight of its own growth.

The empirical analysis identifies road corridor development and ‘grey extensification’ as the primary independent variables. This includes the physical expansion of strategic paths like African Avenue and the prioritization of vehicular mobility over nature-based solutions. Additional independent variables include institutional governance factors, such as the ‘policy-practice gap,’ the lack of agency coordination between the Roads Authority and the Greenery Bureau, and the prevalence of ‘negotiated planning’. Consequently, the dependent variables representing the impacts of these drivers are green space loss and fragmentation, increased surface runoff, urban heat island intensity, traffic accident frequency, and the displacement of livelihoods among peri-urban farmers.

2.4 Theoretical Review

The most instantaneous influence of road-corridor development is the disintegration of the urban landscape. In Addis Ababa, built-up areas rushed to conquer nearly 70.19% of the total land area by 2020, ensuing in an overwhelming 32% loss of green space over the last three decades (Mulatu, 2025). Wearing a way of patch size landscape metrics expose that the city's green network is considered by thrilling disintegration, with 86.2% of individual green patches measuring less than 3000 m² (Woldesemayat & Genovese, 2021). This makes them effectively 'islands' in a sea of concrete, too small to maintenance strong biodiversity or constant microclimates (Cheshmehzangi, 2021). Landscape resistance roads serve as physical barriers (anthropogenic filters) that increase landscape resistance, severing the movement of species and the flow of ecological processes like pollination and seed dispersal (Shackleton & Cilliers, 2022).

Edge density high edge density along major transport routes like African Avenue indicates a highly dissected green space matrix where 'interior' habitat quality is compromised by proximity to pollution, noise, and heat from vehicular traffic. While recent initiatives like the 'complete streets' program aim to incorporate medians and sidewalks, evidence suggests a significant gap between potential and current UGI benefits. For example, along African Avenue, the widening of the road to accommodate motorization has not only consumed previous vegetation but failed to reach its multifunctional potential for storm water management or thermal cooling (Wubengda, 2021).

The shift of Addis Ababa from its historic 'critical urban green space network' characteristics to an Urban Heat Accumulation (UHA) is in a straight line connected to 'grey extensification' motivated by road development (Woldesemayat, 2021). Thermal imbalance enormous areas of paved surfaces, such as asphalt corridors, disperse the heat of the sun slowly, increasing ambient temperatures and health threats for inhabitants (Woldesemayat & Genovese, 2021). UGI components with high tree cover are crucial for cooling, but these are often the first to be sacrificed for road widening projects (Woldesemayat & Genovese, 2021). Hydrological disruption urbanization strangely gives to an escalation in annual surface runoff by up to 413% (Gebreyesus, 2023). Take the place of permeable vegetation with impermeable road surfaces outflows rainfall infiltration, irresistible drainage systems and rising the risk of pluvial flooding during the rainy season (Jacobsen, 2024). Air and noise pollution although UGI acts as a natural filter for air pollutants (PM2.5) and noise, the decline in canopy cover along corridors eliminates these vibrant defensive buffers, leaving pedestrians and nearby residents visible to hazardous levels of pollution (Cheshmehzangi, 2021).

Road corridor developments in Addis Ababa have demanded widespread land expropriations, mainly disturbing peri-urban farmers and inner-city inhabitants (Agona & Abebe, 2024). Displacement of livelihoods ended the past two decades, more than 6,431 farmer families have been evacuated by development projects, leading to a damage of productive land, income, and agricultural production (Agona & Abebe, 2024). Social fragmentation the loss of community green a space the 'communal hubs' for interaction weakens social cohesion and community trust (Taiwo & Green, 2024). In low-income neighborhoods, these spaces serve as 'safety nets,' but they are frequently viewed by planners as 'wasteland' or 'leftover' areas suitable for infrastructure conversion (Mulatu, 2025). Equity gaps there is a widening disparity in green space access; while some 'VIP streets' are aesthetically improved, the park per capita for the average resident has plummeted to between 0.37 and 0.52 m^2, far below the WHO benchmark of 9 m^2 (Woldesemayat, 2021).

The effective integration of UGI and road corridors is hindered by a persistent 'policy-practice gap' and the prevalence of 'negotiated planning' (Mulatu, 2025). Institutional silos duties for road planning and environmental safeguard are regularly divided among dissimilar agencies (e.g., Ethiopian Engineering Corporation vs. the Greenery Bureau), prominent to an absence of synchronization (Gelan & Girma, 2021). This dysfunction has resulted in the destruction of newly built roads to install utility lines or vice versa (Jacobsen, 2024). Ambiguous regulations Ethiopia absences visibly defined and forced green space regulations (Mulatu, 2025). Accordingly, land use policies regularly dominate environmental commands due to social and economic burdens, permitting informal settlements and infrastructure to invade onto sensitive river buffers and forest zones (Shackleton & Cilliers, 2022).

To alleviate these negative effects, cities must implement an adaptive management method that gives UGI as an important urban utility equal to roads (Gelan & Girma, 2021). Nature-Based Solutions (NBS) integrating structures like bio-swales, permeable pavements, and vertical greening into road corridor design can produce a ‘Nature Based Solutions for urban’ capability to manage storm water although bring back ecological connectivity (Gelan & Girma, 2021). Technological discontinuous urban expansion in Addis Ababa has the chance to ‘Urban Sprawl’ the auto-centric development routes of the Global North by shifting straight toward green transportation and non-motorized infrastructures (walking and cycling) (Wubengda, 2021). Participatory planning establishment stakeholder participation and linking local communities in the design of corridors confirm that green spaces reveal cultural values and local needs, improving both ecological and social resilience (D. Wang, 2024).

Environmental sustainability in road corridors is predominantly concerned with alleviating the negative externalities of transportation and improving the city’s capacity to engage environmental shocks. Microclimate regulation and UHA mitigation road corridors are regularly ‘urban canyons’ of asphalt and concrete that setup heat, escalating the Urban Heat Accumulation (UHA) influence (Cheshmehzangi, 2021). UGI, through protecting and evapotranspiration, delivers a ‘cooling effect’ that can lower felt temperatures by numerous degrees (Herodowicz, 2021). Research states that for every 10% increase in UGS, land surface temperatures can drop by approximately 0.4 °C (Woldesemayat & Genovese, 2021). Hydrological guideline urbanization can increase yearly surface runoff by up to 413% due to impermeable road surfaces (Gebreyesus, 2023).

Sustainable road design incorporates Nature-Based Explanations (NBS) such as bios-wales, rain gardens, and permeable pavements to support water infiltration, decrease the burden on traditional drainage systems, and avoid pluvial flooding (Gebru, 2023). Air and noise pollution purification road corridors are crucial sources of Particulate Matter (PM2.5) and gaseous pollutants like nitrogen oxides (City Administration, 2024). Deliberately planted street trees and green verges act as natural filters, catching impurities on leaf surfaces and given that noise abatement buffers that advance the surrounding residential environment (Ugochukwu Kanayo Ashinze, 2024). Biodiversity and ecological connectivity roads regularly act as anthropogenic obstacles that part habitats and split species movement (Shackleton & Cilliers, 2022). By designing corridors as ecological links, cities can smooth wildlife spreading and preserve genetic diversity even in solid urban matrices (Gebru, 2023).

The social aspect underlines the role of green corridors in adopting public health, community belief, and an intellect of belonging. Health and psychological restoration are direct interaction with nature along transport path reduce stress, inspires reflection, and speeds up regaining from mental fatigue (Herodowicz, 2021). The presence of street greenery has a direct visual effect that improves subjective mental health and provides safe areas for physical activity such as walking and cycling (Gebru, 2023). Social cohesion and interaction green corridors serve as 'communal hubs' where residents and travelers interact (Herodowicz, 2021). Well-maintained green spaces increase community trust and social warmth, while their neglect can lead to fear of crime or 'social pathologies' if lighting and maintenance are insufficient (Herodowicz, 2021).

Environmental justice and accessibility sustainability requires that the benefits of UGI are distributed equitably (Ugochukwu Kanayo Ashinze, 2024). In several cities, high-quality greenery is focused in wealthy areas leaving banished communities underserved a phenomenon known as 'green inequality' (Shackleton & Cilliers, 2022). Sustainable corridors must confirm collective access, mainly for vulnerable groups like the elderly, children, and those with disabilities (Gebru, 2023). Cultural and spiritual meaning in the Global South, urban nature is regularly extremely surrounded in cultural identity (Shackleton & Cilliers, 2022). Preserving natural landmarks along corridors such as sacred groves or heritage trees conserves local traditions and supports a community's spiritual connection to the land (D. Wang, 2024).

Economic sustainability involves demonstrating the long-term value of UGI compared to grey infrastructure and its role in supporting local economies. The Proximate principle and property value proximity to well-maintained green infrastructure is consistently linked to increased property values and land desirability (Gebru, 2023). This 'unearned increment' can be harnessed by municipalities through value capture mechanisms to fund further green development (Abdeta, 2025). Infrastructure cost-effectiveness while UGI implementation requires initial investment, it is often more cost-effective than engineered solutions. For instance, nature-based drainage can offer 50% potential savings over conventional piped systems (Nakamura, 2023).

Furthermore, GIs such as urban forests do not incur the enormous maintenance costs associated with decaying concrete infrastructure (Wubengda, 2021). Provisioning services and job creation for the urban poor, UGI provides essential provisioning services, including access to firewood, medicinal plants, and food through urban agriculture (Shackleton & Cilliers, 2022). Additionally, the creation and maintenance of green corridors generate significant employment opportunities for both skilled and unskilled workers (Gebru, 2023).

Achieving sustainability in road-corridor contexts is hindered by a persistent ‘policy-practice gap’ (Jacobsen, 2024). Institutional silos responsibilities for road planning, land administration, and environmental protection are often split among agencies that do not coordinate (Mulatu, 2025). This dysfunction often leads to the destruction of newly built roads to install utility lines or the removal of established trees for road widening (Wubengda, 2021). Negotiated planning in many African cities, environmental mandates are frequently overridden by infrastructure priorities in a process of ‘negotiated planning’ (Mulatu, 2025). Developers may observe green spaces as ‘wasteland’ or ‘leftover’ areas that can be giving up for more ‘economically productive’ uses (Gavrilidis, 2020). Adaptive management pathways to overwhelm these obstacles, cities must implement an adaptive management method an iterative process of planning, monitoring, and adjusting based on response (D. Wang, 2024). This includes participatory planning, where communities are involved in the co-design of corridors to confirm they meet local social and ecological needs (Abdeta, 2025).

Cities in the Global South have the chance to ‘Urban Sprawl’ the auto-centric development models of the Global North (Wubengda, 2021). By incorporating UGI into the very fabric of transportation networks producing ‘complete streets’ that prioritize pedestrians, cyclists, and nature cities can accomplish a nature-positive urban regeneration (Herodowicz, 2021). This needs a fundamental shift in values, where green infrastructure is treated as an important urban utility equal to roads and electricity (Mulatu, 2025). From a theoretical perspective, road-corridor infrastructure serves as an independent variable that dictates landscape metrics, which act as dependent variables; these metrics include patch size, landscape resistance, and edge density. Conversely, when proposing sustainable interventions, Nature-Based Solutions (NBS) and Adaptive Management are treated as independent variables. These interventions positively influence the dependent pillars of sustainability, environmental sustainability, social sustainability and economic sustainability.

2.5 Literature Summary

Urbanization in the Global South has quickly increased, with cities like Addis Ababa undergoing dramatic population growth, horizontal development into peri-urban farmlands, and compact inner-city regeneration, driving widespread transformation of vegetated and agricultural land into impermeable built-up areas. Inside this context, Urban Green Infrastructure (UGI) has appeared as a significant planning model, defined as a tactically planned, multifunctional network of natural and semi-natural areas parks, urban forests, wetlands, river corridors and street greenery designed to provide regulating (climate, flood, and air quality), provisioning, cultural and backup ecosystem services across multiple spatial scales. Essential UGI principles emphasized in the literature contain multi-functionality (each element providing multiple benefits), connectivity (physical and functional links between patches), multi-scale planning, and green–grey integration, where elements green are surrounded into transport and built infrastructure as nature-based solutions.

Empirical work on Addis Ababa documents a profound loss and fragmentation of green space built-up area increased by about 61% between 1986 and 2015, contributing to an estimated 32% decline in green space, while 86.2% of remaining patches are smaller than 3000 m^2, undermining biodiversity, cooling and hydrological functions and reducing per-capita green space to as low as 0.37–0.52 m^2, far below WHO and national standards. Road-corridor development is identified as a central driver of these changes recent renewal programs cover around 40 km of showcase corridors (e.g., African Avenue/Bole Road), justified as congestion relief and ‘smart city’ branding but effectively widening carriageways, hardening surfaces, and replacing vegetation with asphalt and concrete. Studies reveal that such expansions increase surface runoff (up to ~413% in comparable urbanization contexts), exacerbate urban heat islands, and elevate accident risks, especially for pedestrians, while the remaining green elements are narrow, disconnected strips or ornamental plantings that do not function as continuous ecological corridors or storm water systems.

Governance literature emphasizes a policy–practice gap and institutional fragmentation although strategic plans increasingly recognize UGI and propose extensive green networks, implementation is undermined by polycentric but poorly coordinated institutions, weak enforcement, and a culture of 'negotiated planning' where green spaces are treated as 'wasteland' or 'leftover' land that can be sacrificed for roads, housing and investment projects. As a result, UGI distribution is socially inequitable, with high-profile 'VIP streets' and flagship parks upgraded while low-income neighborhoods lose informal and formal green areas and bear the brunt of displacement, cultural landscape loss, pollution and climate risks.

At the same time, global and Ethiopian scholarship demonstrates the potential of UGI in road-corridor contexts to simultaneously regulate microclimate, manage storm water, filter air and noise, support biodiversity, enhance social cohesion and mental health, preserve cultural identity, raise property values and create jobs when corridors are designed as green–blue 'critical urban green space network and Nature Based Solutions for urban storm water management' within the city's 'circulatory system'. Concepts such as adaptive management, Nature-Based Solutions, 'complete streets,' and the Urban Nature Futures Framework are proposed as pathways for Addis Ababa and similar cities to 'Urban Sprawl' car-centric models and embed UGI as a core urban utility on par with roads, water and electricity.

2.6 Research Gap

Regardless of growing conceptual and empirical work on UGI, urban development and governance, the literature exposes a distinct absence of micro-scale, corridor-specific analysis that rigorously quantifies how individual road developments in Addis Ababa disturb the spatial integrity, connectivity and sustainability of the UGI network. Present studies tend to inspect collective land-use routes, green-space accessibility, or city-wide governance matters, rather than merging detailed corridor-level annotations with landscape-ecology metrics such as patch size distributions, connectivity indices and edge density to capture fragmentation and functional loss along exact routes. There is also limited integration of qualitative governance and social perspectives such as the lived experiences of displaced farmers, corridor-adjacent residents, small businesses and everyday users with spatial analyses, leaving the socio-ecological trade-offs of corridor projects under-theorized.

More specifically, the sustainability dimensions of UGI within road-influenced zones how ecological, social, cultural and economic functions co-evolve under current institutional silos and 'negotiated planning' practices remain weakly evidenced, with few context-sensitive tools to evaluate trade-offs between the city's 'circulatory system' (roads) and its 'critical urban green space network and Nature Based Solutions for urban storm water management' (greenery). Finally, participatory, corridor-scale frameworks that translate global best practices in nature-based, 'complete street' design into actionable planning instruments for Addis Ababa such as green-corridor protection rules, compensatory green-space policies and integrated green grey design standards are still largely absent, justifying the need for the proposed study to empirically evaluate corridor impacts and co-produce more robust, locally grounded solutions.

Table 1: Contextual review related to urban green infrastructure.

Theme	Global Findings	African Findings	Addis Ababa Context	Research Gap
Urban Green Infrastructure (UGI)	UGI is recognized globally as a multifunctional system providing ecosystem services such as climate regulation, storm water management, biodiversity support, and urban livability. Integrated green-blue infrastructure and nature-based solutions are increasingly incorporated into sustainable urban planning.	In many African cities, UGI implementation remains fragmented due to rapid urbanization, weak institutional coordination, and limited enforcement of environmental planning standards. Green spaces are often treated as residual land uses rather than strategic infrastructure.	Addis Ababa has experienced substantial green space loss and fragmentation due to rapid urban growth and infrastructure expansion. Existing UGI networks are spatially disconnected, with limited ecological continuity and inadequate per capita green space provision.	Limited empirical studies quantify the spatial integrity and connectivity of UGI under rapid corridor development in Addis Ababa using landscape ecology metrics and geospatial analysis.
Road Corridor Development	Globally, road corridors are increasingly planned using "Complete Street" and sustainable mobility concepts integrating pedestrian facilities, cycling infrastructure, and ecological buffers. Advanced cities incorporate green corridors and low-impact development approaches.	In developing African contexts, road corridor projects are primarily mobility-oriented, with ecological considerations often secondary. Corridor expansion frequently leads to vegetation loss, surface sealing, and ecological disruption.	Addis Ababa's corridor development projects prioritize mobility modernization and urban beautification; however, ecological integration remains weak. Mature indigenous vegetation is frequently removed and replaced with ornamental landscaping.	There is insufficient evidence on how recent corridor expansion projects physically affect UGI continuity, fragmentation, and ecological functionality at the micro-spatial level.
Landscape Fragmentation & Connectivity	International studies use FRAGSTATS, LULC change detection, and landscape metrics	African studies on landscape fragmentation are limited and mainly focus on broad land-	Addis Ababa exhibits increasing fragmentation of green patches, with most green spaces	Lack of localized corridor-scale analysis measuring "barrier effects" and ecological

	(SPLIT, COHESION, LPI, PD) to evaluate ecological fragmentation and habitat connectivity.	use change rather than corridor-induced urban ecological fragmentation.	being small and isolated. Ecological connectivity within dense urban cores such as Piassa remains poorly understood.	severance caused by road infrastructure expansion in Addis Ababa.
Urban Heat & Environmental Quality	Studies globally show that vegetation loss and impervious surface expansion increase urban heat island effects, runoff, and environmental degradation. Street trees and green corridors improve thermal comfort and air quality.	Many African cities experience increasing urban heat stress due to uncontrolled densification and insufficient green infrastructure integration.	Residents in Addis Ababa increasingly perceive warming, inadequate shade, poor pedestrian comfort, and declining environmental quality along corridor developments.	Limited studies integrate spatial ecological metrics with stakeholder perceptions to assess localized environmental impacts of corridor development.
Governance & Policy Integration	Successful international models integrate ecological planning into infrastructure design from early project stages through inter-agency coordination and mandatory environmental frameworks.	African urban governance systems often suffer from institutional fragmentation, weak coordination, and inconsistent implementation of environmental regulations.	In Addis Ababa, ESIAs are often conducted after road design finalization, limiting ecological integration. Coordination gaps exist among AACRA, EEC, and green development institutions.	Limited research examines the institutional and governance dimensions linking policy-practice gaps with ecological fragmentation in corridor development projects.
Nature-Based Solutions (NBS)	Nature-Based Solutions are increasingly integrated into transport infrastructure through bio-swales, permeable pavements, urban forests, and green mobility corridors.	Adoption of NBS in African cities remains limited due to financial, technical, and governance constraints.	Addis Ababa corridor projects incorporate limited landscape beautification measures, but functional ecological integration and canopy continuity remain weak.	Lack of evidence-based frameworks for integrating functional NBS into Addis Ababa's corridor planning and implementation processes.

Source: Compiled from reviewed literature and author's synthesis, 2026.

3. Chapter Three: Methodology

3.1 Study Area

This research focuses on Addis Ababa, Ethiopia a primary urban center experiencing rapid, transformative growth. The study's spatial boundary is specifically delineated as the Piassa district, an area characterized by its historical significance and current role as the epicenter of 'smart city' redevelopment. Within this administrative boundary, the investigation concentrates on major road corridor developments, defined as the primary arterial routes undergoing intensive infrastructure modernization. Piassa was selected as the case study area because it represents the most critical phase of the city's current urban expansion; it serves as a high-density intersection where traditional urban fabric meets aggressive infrastructural transformation, providing a unique vantage point for evaluating the sustainability of modern corridor projects.

Temporally, this research spans an 11-year longitudinal period (2015–2026), a timeframe selected to capture the most intensive phase of Addis Ababa's structural transformation. The study utilizes three primary temporal reference points 2015, 2018, and 2026 to delineate distinct stages of urban evolution. The 2015 baseline marks the initiation of the first Growth and Transformation Plan (GTP I), establishing the pre-expansion state of the city's green corridors. The 2018 midpoint serves as a critical diagnostic year, representing the peak of large-scale arterial road expansions and the transition toward the current administrative urban planning reforms. Finally, 2026 provides the contemporary 'Smart City' data point, allowing for an evaluation of the cumulative impact of recent corridor developments. This temporal framework facilitates a robust assessment of 'grey intensification,' tracing the city's transition from the 'critical urban green space network' to an increasingly fragmented 'urban heat accumulation' as natural ecosystems are replaced by impermeable infrastructure.

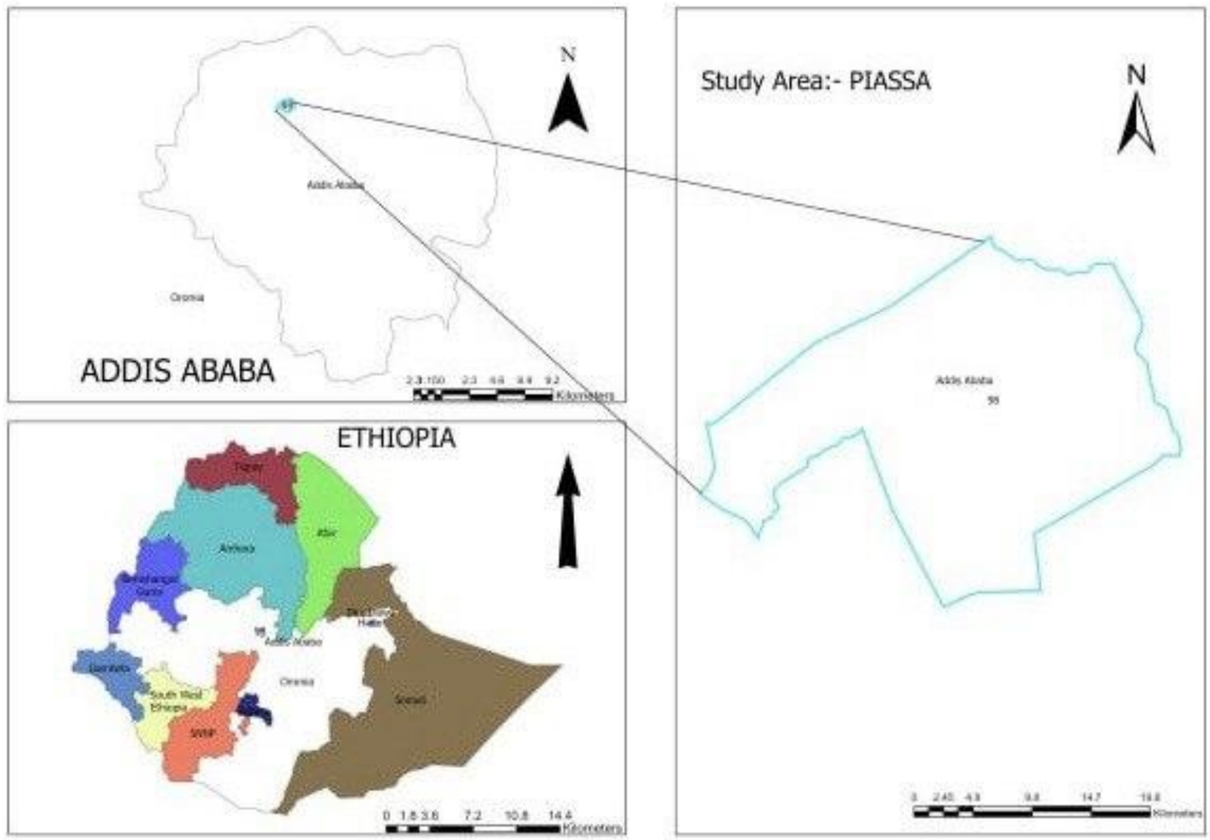


Figure 1: Study Area Location (Piassa, Addis Ababa, Ethiopia) Source: From ArcGIS Pro

3.2 Research Design

This study employs a Mixed-Methods Research Approach utilizing a Sequential Explanatory Design. This framework is structured in two distinct, successive phases where the quantitative results from the spatial analysis inform the focus of the subsequent qualitative inquiry, leading to an integrated synthesis of the 'morpho-functional struggle' in Addis Ababa's urban landscape.

This design proceeds in two distinct phases:

A. Quantitative Spatial Analysis (Priority Phase)

The research implements a descriptive function by mapping, measuring, and quantifying obtainable urban environment and the changes it has undergone.

- ✓ Spatial Quantification: It uses geospatial software to conduct Land Use/Land Cover (LULC) change investigations, providing a factual description of how much green space has been lost to 'grey' infrastructure.
- ✓ Baseline Assessment: It describes the existing spatial relationship between road corridors and Urban Green Infrastructure (UGI) to establish a clear picture of the city's current 'morpho-functional struggle'.
- ✓ Landscape Metrics: The design describes the current state of environmental degradation by calculating precise metrics, such as Mean Patch Size and the Connectivity Index, to provide a numerical representation of habitat fragmentation.
- ✓ Hotspot Identification: Statistical identification of 'environmental crisis zones' where UGI degradation is most acute, which serves as the sampling frame for Phase II.

B. Qualitative Explanatory Inquiry

The second phase adopts an Explanatory Research Design to investigate the institutional and social drivers behind the patterns observed in Phase I.

- ✓ Governance and Policy Investigation: The study explores the effectiveness of current governance and the persistent 'policy-practice gap' through interviews with urban planners and environmental specialists.
- ✓ Qualitative Insights: It explores the 'negotiated planning' practices and institutional silos that lead to infrastructure expansion overriding environmental mandates.
- ✓ Social Impact Exploration: Through community perceptions, the research explores how the loss of green spaces as 'communal hubs' affects social cohesion and human well-being.

3.3 Data Types

The research framework necessitates the integration of two distinct yet complementary data streams to provide a comprehensive evaluation of the study's objectives. The first stream comprises Quantitative Biophysical and Geospatial Data, which serves as the empirical foundation for measuring environmental impact. This dataset utilizes high-resolution satellite imagery to derive Land Surface Temperature (LST) and Land Use/Land Cover (LULC) statistics, enabling the tracking of physical transitions from permeable green surfaces to impermeable 'grey' infrastructure. Furthermore, specific Landscape Ecology Metrics including connectivity indices and patch size calculations are employed to quantify habitat fragmentation. These numerical indicators are directly mapped to the study's objective of assessing the spatial integrity of the urban ecosystem under the pressure of corridor development.

Complementing the statistical evidence is qualitative data, which provides the necessary context to explain the causes and social consequences of the observed physical changes. This category encompasses primary insights drawn from site-specific observations and the 'lived experiences' of those affected by the development. It also includes expert sentiments regarding the management of Urban Green Infrastructure (UGI) and textual data derived from an analysis of legal frameworks, city master plans, and policy documents. By integrating these data types, the research captures both the physical reality of 'grey intensification' and the governance gaps driving it.

3.4 Sources of Data

3.4.1 Primary Data Sources

The research utilizes a multifaceted data collection framework to bridge the gap between institutional policy and urban reality. Primary Data Sources are bifurcated into institutional and social categories: institutional sources include the Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau. Social sources comprise a stratified group of stakeholders within the Piassa district, including residents, business owners, informal workers, and commuters.

3.4.2 Secondary Data Sources

To provide historical and longitudinal context, the study utilizes secondary data from established digital repositories and official archives. The core geospatial data is derived from satellite imagery to track land cover changes since 2015, and high-resolution Sentinel imagery is used for detailed assessments of recent green infrastructure destruction. Google Earth Engine is also utilized for supplementary spatial verification. In terms of documentary evidence, the research relies on official manuals, such as the Addis Ababa 'Complete Street' Manual and the 2018 National Urban Green Infrastructure Standard, alongside relevant legislative proclamations governing urban land use. This is supported by a review of academic literature and peer-reviewed journals focusing on the 'Urban Heat Accumulation' effect and green space decline in Addis Ababa.

3.5 Sampling Design

3.5.1 Sample Population

The study population comprises:

- ✓ Institutional Actors: Officials from the Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau.
- ✓ Spatial Units: The physical land area and green spaces together to the designated road corridors.
- ✓ Local Community: Residents, pedestrians, and informal workers whose livelihoods or living environments are directly affected by the corridor developments.

3.5.2 Sample Size

A. **Spatial Sample Size (Fixed Purposive Sampling)** for spatial analysis, the sample size focuses on the Piassa road corridor segments. While the methodology initially suggests a specific corridor, the scope of the study explicitly delimits the investigation to a representative case study of the Piassa routes. This approach ensures a comprehensive assessment of fragmentation patterns across different eras of development.

B. **Participant Sample Size (Rule of Thumb: Data Saturation)** For the qualitative phase of this study comprising Key Informant Interviews (KIIs) and In-depth Community Interviews the sample size is determined by the principle of Theoretical Saturation. Unlike the quantitative phase, which relies on statistical representation, the qualitative inquiry seeks 'information richness' and the point at which no new thematic insights emerge from the data.

Although the final sample size is contingent upon reaching this saturation point, the research establishes an Expected Participant Range across three primary strata to ensure broad institutional and social representation. This stratified approach ensures that the 'policy-practice gap' is analyzed from the perspective of both the decision-makers and the affected local community in the Piassa district.

- ✓ Determination Rule: The sample size remains flexible during data collection and is considered 'fixed' only when 'Data Saturation' is reached, which is defined as the point in data collection when no new information, themes, or insights are observed in the data.
- ✓ Targeted Participants: Based on this rule, the study targets a purposive sample of institutional actors (from Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau) and a snowball sample of community members (residents and business owners along the corridors). The recruitment of interviewees continues until the responses become repetitive and the research objectives are fully satisfied.

3.5.3 Sampling Techniques

This research employs dual-track sampling techniques to ensure both spatial precision and information richness. The study distinguishes between Spatial Sampling Units and Human Participant Sampling, utilizing distinct criteria for each to maintain methodological rigor.

- ✓ Purposive Sampling: This non-probability method is used to select key informants (experts and officials) based on their specific knowledge and role in urban planning and environmental defense. It confirms that the data composed is relevant and authoritative.
- ✓ Case Study Selection: The specific road corridors (e.g., Piassa Road) are selected purposely rather than arbitrarily to confirm they signify high-impact infrastructure projects that have significantly altered the urban fabric.

3.6 Method of Data Collection

3.6.1 Interviews

To examine the structural and policy-related drivers of green infrastructure degradation, the researcher conducts semi-structured Key Informant Interviews. These interviews target urban planners, environmental specialists, and engineers from key agencies like Addis Ababa City Roads Authority (AACRA), Ethiopian Engineering Corporation (EEC), the study area beautification and cleaning bureau Arada Sub city Woreda 5 (at Woreda level), and the urban beautification & green development bureau. The main objective of this method is to assess the effectiveness of current governance and to deeply explore the 'policy-practice gap,' revealing why infrastructure priorities frequently override environmental mandates. Through direct engagement with these officials, the study aims to extract specific technical knowledge and institutional standpoints that are not available in public documents.

3.6.2 Focus Group Discussions (FGD) / Community Engagement

The study utilizes Focus Group Discussions (FGDs) to capture the collective social experiences and community perceptions of road corridor development. Unlike individual interviews, this method leverages group interaction to identify shared viewpoints and social norms regarding the transformation of the urban landscape. The researcher facilitates structured dialogues with homogenous groups of native residents, business owners, and pedestrians whose daily lives are entwined with the designated Piassa corridors.

This approach is specifically designed to investigate 'social fragmentation' from a community-wide perspective, examining how the loss of vital 'communal hubs' including historical gathering spots and green buffers has altered social cohesion and collective resilience. To ensure diverse yet representative group compositions, participants are recruited using Purposive and Snowball Sampling techniques. The discussions continue across multiple sessions until Theoretical Saturation is reached, defined as the point at which subsequent group dialogues yield no new thematic insights or collective concerns regarding the corridors' socio-ecological impact.

3.6.3 Field Observation

Field observation is utilized as a systematic validation tool to verify the 'grey' versus 'green' spatial patterns identified through remote sensing. This 'ground-truthing' process involves structured site visits to 12 strategically selected observation points along the Piassa road corridors, chosen to represent varying intensities of infrastructure development.

During these visits, the researcher employs a Standardized Observation Checklist to meticulously document UGI variables, including vegetation health (canopy vitality), the presence of integrated drainage (bio-swales), and pedestrian permeability. To ensure high-precision data integration, a GPS/Photo-Documentation Protocol is strictly followed: each observation point is geo-referenced using a handheld GPS device, and a 360-degree digital photographic record is captured to visually document the 'morpho-functional struggle' between expanding road networks and remaining ecological patches.

3.7 Method of Data Analysis

A. Quantitative Data Analysis (Software-Based)

The quantitative analysis follows a multi-stage Geospatial Processing Workflow designed to measure the impact of road corridors on UGI. Primary data is derived from Landsat 8 OLI/TIRS and Sentinel-2A/B imagery, covering three temporal nodes: 2015, 2018, and 2026. All spatial processing is conducted using ArcGIS Pro 3.x and QGIS 3.34 (LTR), integrated with Google Earth Engine (GEE) for historical image composite generation.

To delineate the 'Impact Zone,' a Multi-Ring Buffer Analysis is executed at intervals of 50m, 100m, and 200m, from the road centerlines within the Piassa district. LULC classification is performed using the Random Forest (RF) algorithm, selected for its high accuracy in complex urban environments. Following classification, Landscape Metrics specifically Mean Patch Size (MPS) and the Connectivity Index are calculated using the FRAGSTATS 4.2 engine to quantify habitat fragmentation. To ensure scientific validity, a Confusion Matrix is generated for each time node, targeting an Overall Accuracy (OA) of $\geq$85% and a Kappa Coefficient (Κ) of $\geq$ 0.80, validated against the 12 geo-referenced ground-truth points collected during field observations.

- Software Used: The document requires the use of GIS software to procedure satellite imagery (LANDSAT and Sentinel).
- Analysis Performed:

✓ Land Use/Land Cover (LULC) Change Detection: The software is used to categorize land use types and extract green infrastructure layers to measure the damage of green space over the 11-year period.

✓ Landscape Metrics Calculation: Specific metrics are calculated (likely within the GIS environment or using spatial analysis extensions) to measure spatial integrity. These include Mean Patch Size (MPS) to evaluate the reduction in green area size, the Connectivity Index to assess isolation, and Edge Density to measure fragmentation.

✓ Statistical Output: The results are presented as statistical charts and tables to quantify trends.

B. **Qualitative Data Analysis (Thematic & Narrative)**

The qualitative data, derived from in-depth interviews, focus group discussions, and institutional document reviews, is examined using Thematic Analysis (TA). The analysis follows a rigorous, manual six-phase protocol comprising data familiarization, initial code generation, searching for themes, reviewing themes, defining themes, and final reporting.

The coding process is executed through a hybrid inductive-deductive approach:

- ✓ Deductive Coding: Pre-defined codes are applied to identify 'policy-practice gaps' and 'institutional silos' within official road corridor mandates.
- ✓ Inductive Coding: Emergent themes, such as 'social fragmentation' and the 'loss of communal hubs,' are identified directly from participant narratives to capture unanticipated social impacts.

To ensure methodological transparency, a Standardized Codebook is maintained to categorize 'meaning units' into sub-themes. These themes are then systematically mapped back to the primary research questions, providing a narrative explanation for the spatial UGI degradation identified in the quantitative phase. The reliability of the manual interpretation is further strengthened through triangulation with field observations and member-checking with key informants in the Piassa district.

- Method Used: The document explicitly selects Thematic Analysis.
- Process:
- ✓ Transcription and Coding: Data from Key Informant Interviews and In-depth Community Interviews is first transcribed and then coded.
- ✓ Pattern Recognition: The analysis identifies recurring themes and patterns, such as negotiated planning, institutional silos, and displacement.
- Narration: The final output is presented through Narrative Descriptions. This method is used to convey the ‘lived experiences of the community and detailed policy evaluations, providing the context that explains why the spatial patterns identified by the software are occurring.

3.8 Method of Data Presentation

A. Statistical Tables

Tables are used to provide exact numerical summaries of the biophysical changes witnessed over the 11-year period.

- ✓ Land Use/Land Cover (LULC) Matrix: A comparative table presents the total area (in hectares) and percentage share of each land use class (e.g., Built-up/Paved, Green Space, Water Body) for the years 2015 and 2026. This permits a direct 'before and after' comparison of the road corridors.

- ✓ Landscape Metrics Table: A specific table presents the calculated values for Mean Patch Size (MPS), Connectivity Index, and Edge Density for the Piassa case study corridor. This table effectively quantifies the degree of fragmentation and isolation of green patches caused by road expansion.

B. Graphs and Charts

Visual statistical tools are utilized to clarify trends and comparative magnitudes of 'grey intensification' versus green space loss.

- ✓ Bar Charts: Clustered bar charts are generated to visually relate the degree of green space versus built-up areas across the three time-points (e.g., 2015, 2018, 2026), highlighting the scale of land conversion.

- ✓ Trend Line Graphs: Line graphs are employed to plot the rate of vegetation decline over the 11-year period, visualizing the speed at which the city transitions from a 'green lung of highlands' to an 'urban heat trap.'

- ✓ Pie Charts: These are used to show the composition of the remaining Green Infrastructure (e.g., percentage of shrubs vs. trees vs. grass) within the specific road-corridor influence zones.

C. Maps and Spatial Models

Geospatial visualizations serve as the primary method for presenting the physical transformation of the study area.

- ✓ LULC Change Detection Maps: The study presents side-by-side or overlaid GIS maps showing the land cover of Addis Ababa for 2015 and 2026. These maps use distinct color coding (e.g., Red for new built-up areas, Green for lost vegetation) to visually identify ‘hotspots’ where road developments have most severely compromised UGI.

- ✓ Fragmentation Maps: Specific spatial models visualize the ‘Connectivity Index, highlighting areas where the green network is severed by road barriers (anthropogenic filters).

D. Narrative Descriptions (Qualitative Presentation)

While tables and charts present the extent of change, narrative text explains the underlying causes.

- ✓ Thematic Narratives: Results from Key Informant Interviews and Community Discussions are presented as narrative descriptions. These are organized by themes (e.g., ‘Policy-Practice Gap,’ ‘Displacement’) to clarify the governance failures and social influences behind the statistical trends.

3.9 Validation and Reliability

To ensure the scientific rigor and credibility of the results, the study employs a dual-track validation framework specifically tailored to the distinct requirements of spatial and qualitative datasets.

A. Spatial Data Accuracy (Quantitative): The reliability of the Land Use/Land Cover (LULC) classification is verified through a Confusion Matrix. This statistical procedure compares the classified satellite output against 12 geo-referenced ground-truth points and high-resolution reference imagery. The study targets an Overall Accuracy (OA) of $\geq$ 85% and a Kappa Coefficient (K) of $\geq$ 0.80. These metrics provide a quantifiable measure of 'Producer’s Accuracy' (how well the area is mapped) and 'User's Accuracy' (how reliable the map is for a user on the ground in Piassa).

B. Qualitative Trustworthiness (Interpretative): The rigor of the Focus Group Discussions and document reviews is established through the criteria of Credibility, Dependability, and Transferability.

- ✓ Credibility is ensured through Methodological Triangulation, where interview narratives are cross-referenced with field observations and official technical designs from EEC.
- ✓ Dependability is maintained through a Manual Audit Trail, documenting every step of the thematic coding process from raw transcript to final theme.
- ✓ Member-Checking is utilized by sharing preliminary thematic findings with select community participants in Piassa to confirm that the interpretations accurately reflect their lived experiences.

3.10 Ethical Considerations

Given the sensitive nature of assessing government policy and identifying institutional gaps, the research adheres to strict ethical protocols to protect participant confidentiality and ensure data integrity.

- ✓ Anonymization and Identity Protection: To mitigate the risk of professional or social repercussions, all human participants are assigned unique alphanumeric identifiers (e.g., Participant-KII-01 or Resident-FGD-A). Real names, specific job titles, and identifying personal details are scrubbed from all transcripts and final reports to ensure that no individual can be linked to their specific feedback.
- ✓ Transcript and Record Handling: Interview and FGD recordings are transcribed immediately and stored in encrypted, password-protected digital folders. Once transcription and 'member-checking' are complete, the original audio files are permanently deleted to prevent unauthorized voice identification.
- ✓ Management of Visual Data: Photographs captured during field observations are used strictly for morpho-functional analysis. Any incidental captures of human faces or private

property markers (e.g., house numbers) are blurred or cropped during the post-processing phase to maintain bystander anonymity.

- ✓ Secure Storage and Retention: All primary data, including coded spreadsheets and geo-referenced field notes, are stored on a secure, offline external drive with a secondary encrypted cloud backup accessible only to the primary researcher. In accordance with academic standards, all raw data will be securely retained for a period of five years post-defense, after which all digital and physical records will be permanently destroyed.

4. Chapter Four: Result and Discussion

4.1 Introduction

This chapter presents the results and discussion of the study examining urban green infrastructure (UGI) transformation in the Piassa district of Arada sub-city, Addis Ababa. The analysis focuses on the Kechene river corridor development and the creation of Arada Park, implemented under the Addis Ababa Mayor's Office River Corridor Programme and the Prime Minister's Green Legacy Initiative. The study addresses three core research objectives: assessing changes in the spatial extent and configuration of UGI; evaluating user perceptions of microclimate, connectivity, environmental quality, and livability; and examining the institutional and governance factors that have shaped programme outcomes.

Three complementary data sources inform this chapter. First, a structured questionnaire survey was administered to 60 respondents drawn from residents, workers, students, business owners, and pedestrians in the study area. This source addresses the second research objective by capturing user perceptions of green space access, connectivity, environmental quality, and future expectations. Second, multi-temporal satellite remote sensing analysis compares land use and land cover (LULC) conditions between 2015 and 2026. This source directly addresses the first objective by quantifying structural changes in the green matrix, including patch size, fragmentation, cohesion, and spatial connectivity. Third, key informant interviews were conducted with technical experts, urban planners, and local stakeholders. This source addresses the third objective by contextualizing spatial findings within the institutional, governance, and design dynamics that have enabled or constrained programme outcomes. Together, these methods provide a triangulated account of UGI transformation across spatial, perceptual, and institutional dimensions.

The chapter is organized into five thematic sections. The first profiles the socio-demographic characteristics of survey respondents. The second examines perceptions of green infrastructure connectivity and microclimate perceptions. The third analysis perceived environmental and livability impacts of the corridor redevelopment. The fourth addresses nature-based solutions, public consultation, and future expectations. The fifth integrates satellite-derived landscape metrics with field triangulation data to quantify the structural transformation of the green matrix.

The chapter concludes with qualitative analysis from key informant interviews, which contextualizes the spatial findings within the institutional and governance dynamics that have shaped and, in some cases, constrained the outcomes of the corridor development programme.

4.2 Results

The results are organized into five sequential sub-sections, each addressing a distinct analytical layer. The first sub-section characterizes the socio-demographic profile of the 60 survey respondents, establishing the representativeness of the sample and its relevance to UGI use patterns in the study area. This profile is essential for interpreting the perception data that follows. The second and third sub-sections present structured survey findings on green infrastructure connectivity and microclimate perceptions, and on perceived environmental and livability impacts respectively; together, these documents show how corridor users experience the transformation of Piassa's green matrix.

The fourth sub-section reports respondent expectations regarding nature-based solutions, public consultation, and compensatory greening, revealing a clear community mandate for more sustainable and participatory corridor planning. The fifth sub-section moves from perception to measurement, integrating multi-temporal satellite remote sensing analysis and FRAGSTATS landscape metrics with field triangulation data to quantify structural changes in green cover, patch cohesion, and spatial connectivity between 2015 and 2026. The chapter concludes with qualitative findings from key informant interviews, which provide the institutional and governance context necessary to explain the patterns observed across all preceding data layers.

4.2.1 Profile of the research participants

In this section the demographic characteristics of respondents, who are the selected stakeholders, are generally described in terms of the questionnaires and interviews. These variables include sex, age of the respondents, main role in the area, and Length of familiarity with the area. The subsequent section focused on the Access and Spatial Integration UGI in Addis Ababa. The last section discusses profile of interviewees that was based on research objectives. The summaries of participants are described in detail on the next subsequent sections.

A. The socio demographic data of respondents

Table 2: Socio-demographic Characteristics of Respondents in the Study Area

Sex	Freq	%	Age	Freq	%	Main role in the area	Freq	%	Length of familiarity with the area	Freq	%
Male	32	53.3	20-29	19	31.7	Resident	15	25	Less than 1 year	3	5
Female	27	45	30-39	17	28.3	Business owner	4	6.7	1-3 year	6	10
Prefer not to say	1	1.7	40-49	17	28.3	Worker	11	18.3	4-7 year	12	20
			50 and above	7	11.7	Student	15	25	8-12 year	14	23.3
						Pedestrian	15	25	More than 12 years	25	41.7

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 1 summarizes the socio-demographic profile of the 60 survey respondents in the Piassa study area. The sample was drawn from five participant categories residents, workers, students, business owners, and pedestrians and is characterized across four variables: sex, age, main role in the area, and length of familiarity with the district. This profile is analytically significant because the credibility of perception-based findings depends on the diversity and tenure of those surveyed. A sample that spans multiple user roles and includes a high proportion of long-term residents is better positioned to evaluate change in green infrastructure over time than one concentrated among transient or single-category users.

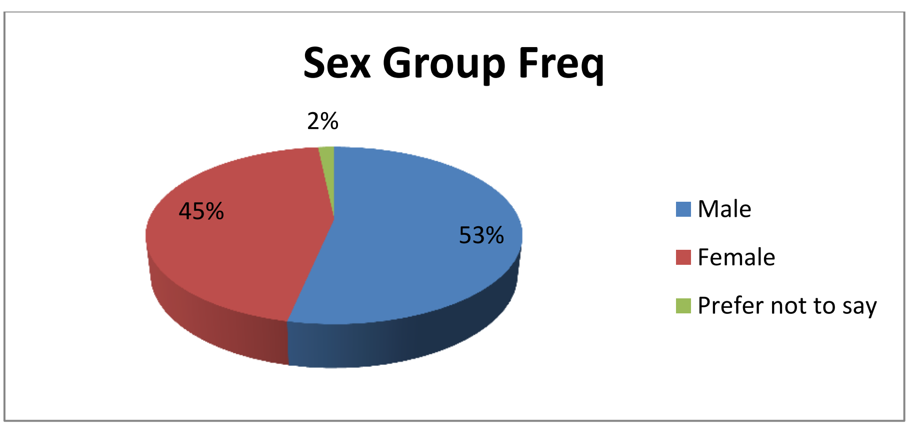


Figure 2: Distribution of Survey Respondents by Sex in the Study Area. Source: Survey results, SPSS output, 2026

The sample is near-gender-balanced, with a slight male majority (53.3% male, 45% female, 1.7% preferring not to state). This distribution is appropriate for a UGI perception study in Piassa, where public spaces including the corridor, park, and street network are used across gender lines for daily mobility, commerce, and recreation. Gender balance in the sample reduces the risk of a systematically skewed reading of space quality and access, and supports more representative conclusions about how corridor development has been experienced by the broader user population.

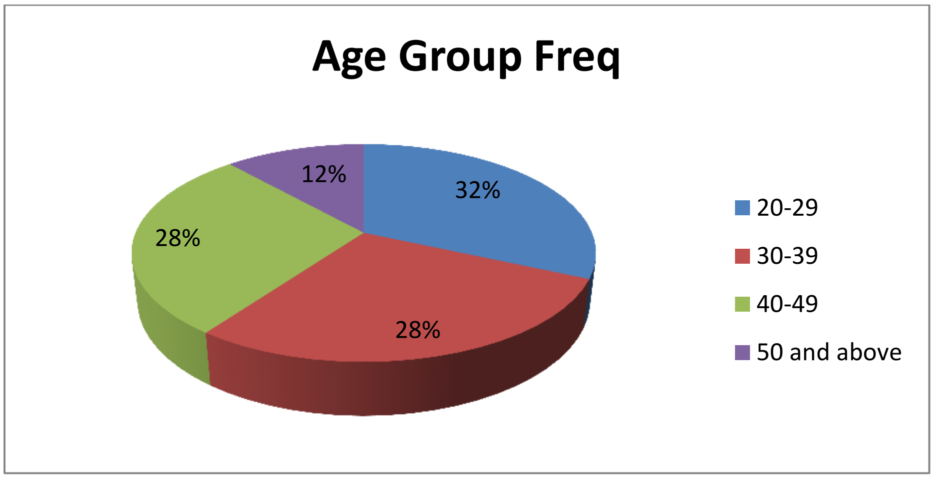


Figure 3: Distribution of Survey Respondents by Age in the Study Area. Source: Survey results, SPSS output, 2026.

The age distribution is skewed toward younger and middle-aged adults: 31.7% are aged 20–29, 28.3% are 30–39, and 28.3% are 40–49, making 88.3% of the sample between 20 and 49 years of age. This profile corresponds well with the active user population of urban parks and pedestrian corridors in Addis Ababa's inner core. Respondents in this age range are likely to be frequent, mobile users of green infrastructure features such as walkways, recreational spaces, and transit corridors, making their perceptions directly relevant to assessments of connectivity and livability. The limited representation of respondents aged 50 and above (11.7%) is a noted constraint: this cohort may hold distinct views on accessibility, maintenance quality, and thermal comfort that are underweighted in the aggregate findings. No respondents under 20 were captured, reflecting the adult-oriented sampling frame.

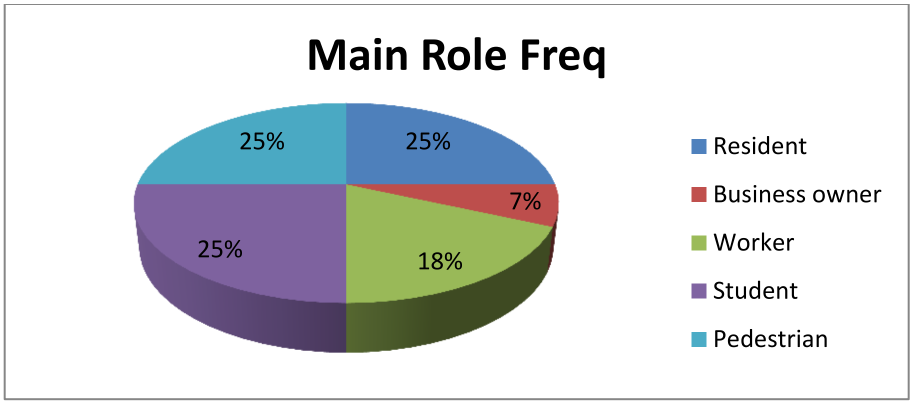


Figure 4: Distribution of Survey Respondents by Main role in the Study Area Source: Survey results, SPSS output, 2026.

Role distribution is well-balanced: residents, students, and pedestrians each account for 25% of the sample, workers for 18.3%, and business owners for 6.7%. This composition is well-suited to a UGI study in Piassa, which functions simultaneously as a residential district, an educational and transport hub, and a commercial corridor. Residents and workers are positioned to evaluate the long-term and daily-use dimensions of green infrastructure change, including impacts on access, thermal comfort, and communal space. Students and pedestrians, who together comprise half the sample, are particularly relevant to perceptions of pedestrian connectivity, shade provision, and corridor walkability outcomes central to this study's second research objective. The lower representation of business owners (6.7%) may introduce a slight under-representation of commercial-use perspectives, though this is consistent with the study's primary focus on public space users rather than proprietors.

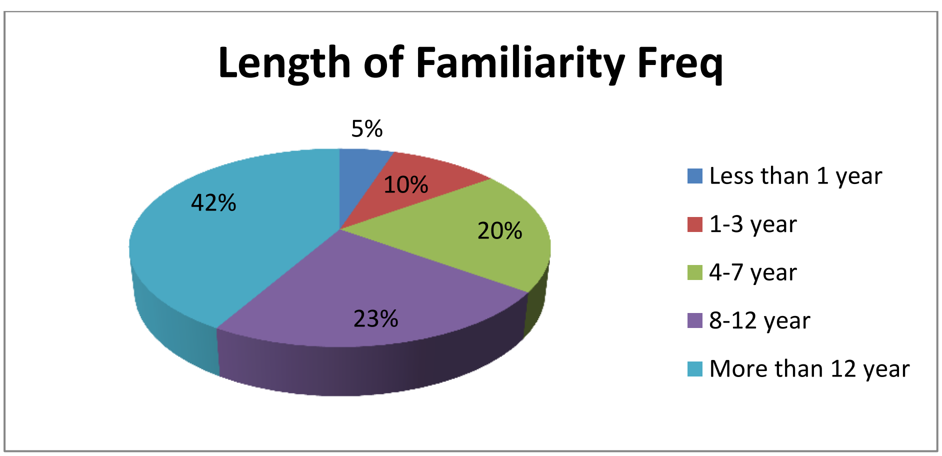


Figure 5: Length of familiarity with the area Source: Survey results, SPSS output, 2026.

Length of familiarity with the study area provides a key indicator of the depth of respondents' comparative perspective. A strong majority, 65% have been familiar with Piassa for eight years or more, and 41.7% for over twelve years. This sub-group is analytically most valuable for evaluating before-and-after conditions, as they were present prior to the Kechene corridor redevelopment and the creation of Arada Park. Their perceptions of changes in green space access, thermal comfort, and community characters carry greater evidential weight than those of shorter-term respondents. 15% of those with fewer than four years of familiarity are more likely to include new users attracted by improved green and public spaces and may rate current conditions more favorably in the absence of a pre-intervention baseline. Taken together, the tenure structure of the sample supports credible comparative judgments across the full range of perception-based findings reported in subsequent sub-sections.

4.2.2 Connectivity and Microclimate Perceptions of Urban Green Infrastructure

Table 3: Descriptive statistics for connectivity and spatial integration

S.No	Statement	Mean	Std. Deviation
1	Access to trees, planted areas, or public green spaces has decreased after the recent road corridor development	1.97	0.92
2	The current road corridor provides adequate shade for pedestrians during daytime movement	2.62	1.091
3	Street trees and other natural elements are well integrated into the design of the corridor	3.43	1.064
4	The new road design has improved structural connectivity of urban green infrastructure	3.83	0.886
5	Important communal gathering spaces have been reduced or displaced by the road project	2.32	0.93
6	The current corridor design gives more attention to vehicles than to ecological and public-space functions	3.7	0.944

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 2 presents descriptive statistics for six perception statements addressing green infrastructure connectivity and spatial integration. The results reveal a pattern of selective improvement: the corridor redevelopment has demonstrably advanced structural and pedestrian connectivity yet has simultaneously generated significant deficits in ecological function and thermal comfort and reinforced a vehicle-oriented design logic that constrains the corridor's capacity to perform as genuine urban green infrastructure. It is important to distinguish between three forms of connectivity at stake here. Structural connectivity refers to the physical continuity and cohesion of the green matrix, the degree to which vegetated patches are spatially linked.

Pedestrian connectivity concerns the ease and comfort with which people can move through and between green and public spaces on foot. Ecological connectivity denotes the capacity of the green network to support biological processes, regulate microclimate, and function as habitat. The survey findings indicate that the corridor scores most positively on structural and pedestrian connectivity but performs poorly on the ecological and thermal dimensions that underpin long-term corridor sustainability. The strongest finding is that 70% of respondents perceive the design as prioritizing vehicles over ecological and public-space functions (Mean = 3.70, SD = 0.944) is not merely a design preference. It signals a structural contradiction: a corridor designated as urban green infrastructure that, in practice, functions primarily as a traffic artery. This contradiction has direct consequences for ecological connectivity, shade provision, and the long-term livability of the corridor.

A. Green Space Access: Maintained, Not Expanded

Table 4: Respondent Ratings on the Impact of Road Development on Green Space Accessibility (N=60)

Options	Frequency	Percent
Strongly disagree	21	35
Disagree	24	40
Neutral	12	20
Agree	2	3.3
Strongly agree	1	1.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

A large majority of respondents (75%) disagreed that access to trees, planted areas, or public green spaces had decreased following the corridor redevelopment, and only 5% reported a perceived decline. This finding indicates that the project has succeeded in preserving baseline green space access a necessary but insufficient condition for a corridor that aspires to enhance urban ecological quality. Importantly, the data reflects perceived maintenance of access rather than a positive expansion. In a context where total vegetated area increased by 158.9% between 2015 and 2026 (Section 4.2.5), user perception of unchanged or marginally improved access suggests that the new green spaces may be spatially concentrated or functionally inaccessible in ways that limit their contribution to everyday green space experience. This finding warrants caution: aggregate green cover gains do not automatically translate into perceived improvements in distributed access.

B. Shade Deficiency: A Thermal Comfort and Walkability Failure

Table 5: Respondent Perceptions of Pedestrian Shade Adequacy along the Road Corridor

Options	Frequency	Percent
Strongly disagree	5	8.3
Disagree	31	51.7
Neutral	11	18.3
Agree	8	13.3
Strongly agree	5	8.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Shade provision represents the most acute functional deficit identified in this sub-section. A clear majority (60%) of respondents reported that the current corridor does not provide adequate shade for pedestrians during daytime movement, and only 21.6% expressed satisfaction with shade levels. This finding is analytically significant for three reasons. First, shade directly determines pedestrian thermal comfort: inadequate canopy cover increases exposure to solar radiation and amplifies the urban heat island effect, a concern already flagged by 65% of respondents in the environmental impacts sub-section.

Second, thermal discomfort suppresses walkability: in a district where 70% of the population moves primarily on foot, a shade-deficient corridor discourages the active use that green infrastructure is intended to promote. Third, the deficiency reflects a climate-insensitive design approach: a corridor that prioritizes carriageway width and visual landscaping over functional tree canopy fails to meet the standards expected of climate-responsive urban infrastructure. The replacement of mature indigenous street trees with younger, narrower plantation species during road widening confirmed by key informant interviews provides the direct mechanism linking corridor design decisions to this thermal performance gap. Future corridor designs should treat canopy continuity as a non-negotiable infrastructure requirement, not an aesthetic supplement.

C. Street Tree Integration: Positive Perception, Partial Achievement

Table 6: Perceptions of the Integration of Street Trees and Natural Elements along the Corridor

Options	Frequency	Percent
Strongly disagree	4	6.7
Disagree	10	16.7
Neutral	6	10
Agree	36	60
Strongly agree	4	6.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Two-thirds of respondents (66.7%) agreed that street trees and natural elements are well integrated into the corridor design, while 23.4% disagreed a minority that is nonetheless substantial given the scale of the investment. This finding should be interpreted alongside the shade adequacy result. Perceived integration of street trees does not imply functional adequacy: trees may be present and visible without yet providing sufficient canopy cover for thermal protection, particularly where planting is young or species selection prioritizes ornamental over climate-regulating function. The 23.4% dissatisfied with integration likely includes respondents attuned to the ecological distinction between decorative greening and structurally embedded vegetation. Planning implication: integration assessments should be complemented by canopy cover measurements and thermal performance data to distinguish between cosmetic and functional green infrastructure.

D. Pedestrian Connectivity: The Clearest Positive Outcome

Table 7: Perceptions of the Impact of New Road Design on Pedestrian Connectivity

Options	Frequency	Percent
Disagree	8	13.3
Neutral	5	8.3
Agree	36	60
Strongly agree	11	18.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Pedestrian connectivity the ease of movement between activity areas and green or public spaces records the strongest positive outcome in this sub-section. A substantial majority (78.3%) perceived the new road design as having improved pedestrian connectivity, with only 13.3% disagreeing. This result is consistent with the provision of new sidewalks, crossing facilities, and landscaped pedestrian paths documented in the project. However, pedestrian connectivity improvement must be distinguished from ecological connectivity enhancement. Wider footpaths and improved crossings increase human movement capacity; they do not, by themselves, restore or improve the ecological network functions pollinator pathways, microclimate regulation, storm water absorption that define a genuinely functional UGI corridor. The risk is that high pedestrian connectivity scores are used to characterize the corridor as UGI-effective when the ecological connectivity evidence points in a different direction. Both dimensions must be tracked independently in corridor assessments.

E. Communal Space Displacement: Largely Unconfirmed, But Not Absent

Table 8: Respondent Perceptions Regarding the Reduction of Communal Gathering Spaces.

Options	Frequency	Percent
Strongly disagree	9	15
Disagree	33	55
Neutral	8	13.3
Agree	10	16.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

A strong majority (70%) of respondents disagreed that communal gathering spaces had been reduced or displaced by the road project, and only 16.7% perceived a loss. Taken at face value, this result suggests the corridor has not significantly disrupted social space. However, it should be read with caution for two reasons. First, the 16.7% who did perceive displacement represents approximately ten respondents in a small sample a minority that may disproportionately include those most directly affected by relocation tied to corridor clearance. Second, respondents with fewer than four years of familiarity cannot serve as reliable witnesses to pre-intervention communal space conditions. Qualitative interview data corroborates the view that social density and informal gathering functions have declined even where physical displacement is not formally acknowledged. The aggregate survey figure therefore likely underestimates the social disruption experienced by longer-tenured residents.

F. Vehicle Priority Over Ecological and Public-Space Functions: A Critical Design Tension

Table 9: Perceptions of the Corridor Design's Prioritization of Public Space.

Options	Frequency	Percent
Strongly disagree	2	3.3
Disagree	5	8.3
Neutral	11	18.3
Agree	33	55
Strongly agree	9	15
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

The most critically significant finding in this sub-section is that 70% of respondents across all role categories agree that the current corridor design prioritizes vehicles over ecological and public-space functions (Mean = 3.70, SD = 0.944). The low standard deviation confirms this is a consistent perception rather than a polarized one. This finding carries substantial implications for how the corridor should be evaluated as urban green infrastructure. A design that respondents perceive as vehicle-first is one in which carriageway width, traffic throughput, and road engineering logic have taken precedence over the ecological, thermal, and social functions that UGI is expected to deliver.

The consequence is visible across multiple indicators in this sub-section: shade is inadequate because canopy planting is subordinated to road geometry; communal spaces are reduced because public realm is compressed to accommodate traffic lanes; ecological connectivity is weakened because the corridor is engineered as infrastructure rather than habitat. Vehicle-oriented design is not simply an aesthetic shortcoming; it is the underlying design logic that explains several of the functional deficits reported here. Correcting this requires a reorientation of corridor design standards embedding green infrastructure requirements, canopy targets, and ecological performance benchmarks into the road design brief itself, rather than treating them as post-hoc additions. The near-unanimous demand for stronger green infrastructure requirements in future a project (86.6%, Section 4.2.4) indicates that this reorientation is both needed and publicly supported.

The table evaluates whether the current corridor design prioritizes vehicles over ecological and public-space functions. A significant majority of the 60 respondents 70% in total coincide with this assessment, with 55% (33 people) agreeing and 15% (9 people) strongly agreeing. In contrast, only 11.6% expressed disagreement, while 18.3% (11 people) remained neutral. These findings indicate a strong public perception that the design favors vehicular traffic at the expense of environmental and social considerations.

4.2.3 Perceived Environmental and Livability Impacts

Table 10: Descriptive Statistics of Perceived Environmental and Livability Impacts.

S.No	Statement	Mean	Std. Deviation
1	The area feels warmer now than before the road corridor redevelopment.	3.55	0.91
2	There is less shade and thermal comfort for walking than in the past.	2.6	1.012
3	Rainwater runoff and surface water accumulation are more visible now than before.	2.72	0.993
4	Air quality and dust conditions have worsened during or after corridor construction.	2.38	1.01

5	The current street environment is comfortable for walking, waiting, and social interaction.	3.98	1.017
6	Loss of greenery has negatively affected the attractiveness and identity of the area.	3.95	0.891

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 9 presents descriptive statistics for six perception statements addressing environmental and livability impacts of the corridor redevelopment. A Likert scale (Joshi, 2015) of 1 (strongly disagree) to 5 (strongly agree) was used throughout: higher mean values indicate stronger agreement with the statement tested, and the direction of each statement therefore determines whether a high or low score constitutes a positive or negative finding. The results present an analytically important contradiction. On one hand, the corridor scores highest on street-level comfort for walking, waiting, and social interaction (Mean = 3.98), and respondents strongly perceive that greenery loss has negatively affected the area's attractiveness and identity (Mean = 3.95). On the other hand, 65% of respondents perceive the area as warmer than before (Mean = 3.55), and 60% find shade provision inadequate (Section 4.2.2). This apparent contradiction is not inconsistent.

General livability measured through pavement quality, cleanliness, spatial orderliness, and pedestrian infrastructure has demonstrably improved as a result of corridor formalization. Thermal comfort, however, depends on a different set of conditions: continuous tree canopy, vegetated surfaces, and shaded rest points. These remain deficient. In short, the corridor has been successfully urbanized but not yet ecologically performed. Respondents can simultaneously experience a cleaner, more walk able street and a hotter, less shaded one. The two outcomes reflect different design decisions: pavement and infrastructure investment has been delivered; canopy investment has not. The greenery-loss finding further complicates this picture. With a mean of 3.95 and 81.6% agreement, this is the second-strongest finding in the section. It signals that residents perceive more than a functional deficit: they register a loss of landscape character, urban memory, and place identity dimensions of green infrastructure value that aggregate metrics of green cover cannot capture.

A. Perceived Warming: Urban Heat Trap Signal and Canopy Deficit

Table 11: Perceptions of Temperature changes following the Road Corridor Redevelopment.

Options	Frequency	Percent
Strongly disagree	1	1.7
Disagree	9	15
Neutral	11	18.3
Agree	34	56.7
Strongly agree	5	8.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

A majority of respondents (65%) agreed that the area feels warmer following the corridor redevelopment, and only 16.7% disagreed. On a 1–5 agreement scale, a mean of 3.55 represents clear majority agreement with the warming statement. This finding is consistent with established urban heat island (UHI) dynamics. When mature trees are removed during road widening and replaced with younger, narrower-canopied species, the thermal buffering capacity of the corridor diminishes. Simultaneously, the expansion of impervious surfaces carriageway, kerbs, and paving increases heat absorption and reduces evapotranspiration, intensifying surface and ambient temperatures.

Key informant interviews confirmed that mature indigenous street trees were removed during construction and replaced with ornamental plantation species that provide limited canopy coverage in the short to medium term. In a district where pedestrians constitute the majority of corridor users, a measurable perceived warming is both a comfort failure and a public health risk during peak summer months. Planning implication: future corridor designs should mandate canopy continuity standards, specify minimum tree maturity for replacement planting, and priorities locally adapted species with broad crown spread over ornamental alternatives.

B. Rainwater Runoff and Air Quality: Infrastructure Improvement Without Ecological Regression

Table 12: Perception of Rainwater Runoff and Surface Water Accumulation Visibility.

Options	Frequency	Percent
Strongly disagree	2	3.3
Disagree	31	51.7
Neutral	12	20
Agree	12	20
Strongly agree	3	5
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 13: Perceptions of Air Quality and Dust Conditions following the Corridor Redevelopment.

Options	Frequency	Percent
Strongly disagree	9	15
Disagree	31	51.7
Neutral	10	16.7
Agree	8	13.3
Strongly agree	2	3.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

For both rainwater runoff and air quality, the majority of respondents disagreed that conditions had worsened: 55% disagreed that runoff and surface water accumulation had increased (Mean = 2.72, where agreement would indicate deterioration), and 66.7% disagreed that air quality and dust had worsened (Mean = 2.38). On the 1–5 scale used, means below 3.0 on negatively framed statements indicate that most respondents do not perceive the condition described as a problem these are not neutral scores but expressions of disagreement with a negative claim. The results suggest that engineered drainage improvements and dust suppression measures introduced during corridor construction have been effective from a user perspective.

This is an important finding: it indicates that the corridor has successfully managed two of the environmental risks most commonly associated with urban road development. However, the absence of perceived worsening is not equivalent to ecological improvement. Increased impervious coverage increases total runoff volume even when drainage infrastructure handles it efficiently, reducing groundwater recharge and removing the storm water absorption function that vegetated soils provide. Planning implication: drainage performance should be assessed using both perceptual survey data and hydrological measurements, as user satisfaction with drainage does not capture the underlying loss of permeable surface and green storm water infrastructure.

C. Street-Level Comfort: A Livability Gain Distinct from Thermal Performance

Table 14: Perceptions of Street Environment Comfort for Walking, Waiting, and Social Intersection.

Options	Frequency	Percent
Strongly disagree	2	3.3
Disagree	5	8.3
Neutral	4	6.7
Agree	30	50
Strongly agree	19	31.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Street-level comfort for walking, waiting, and social interaction records the strongest positive finding in this sub-section, with 81.7% of respondents in agreement (Mean = 3.98, SD = 1.017). This result reflects genuine infrastructure improvements: paved walkways, formal crossing facilities, improved lighting, and tactile paving for visually impaired users have materially enhanced the pedestrian environment. The finding must, however, be analytically separated from thermal comfort. General street comfort encompasses pavement quality, spatial order, and social atmosphere dimensions that have improved. Thermal comfort depends on shade, canopy continuity, and surface temperature dimensions that remain deficient (60% of respondents find shade inadequate, Section 4.2.2).

A pedestrian can simultaneously find the street well-paved and too hot: both assessments are accurate and compatible. Conflating general walking comfort with thermal comfort would misrepresent the corridor’s livability performance. The high comfort score reflects the success of civil infrastructure investment; the shade and warming scores expose the ecological gap that investment has not yet filled. Planning implication: livability assessments for corridor projects should disaggregate general pedestrian comfort from thermally sensitive indicators, and both should be reported independently rather than aggregated into a single satisfaction measure.

D. Greenery Loss and Landscape Identity: Ecological and Cultural Dimensions

Table 15: Perceptions of the Negative Impact of Greenery Loss on the Study Area.

Options	Frequency	Percent
Strongly disagree	2	3.3
Disagree	2	3.3
Neutral	7	11.7
Agree	35	58.3
Strongly agree	14	23.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

The statement that loss of greenery has negatively affected the attractiveness and identity of the area records the second-highest mean in this sub-section (Mean = 3.95, SD = 0.891), with 81.6% of respondents in agreement. The low standard deviation confirms this is a broadly shared perception rather than a divided one. This finding operates on two distinct dimensions that planning analysis should not conflate. Ecologically, the loss of established vegetation particularly mature trees removed during road widening reduces canopy cover, diminishes habitat connectivity, decreases evapotranspiration, and weakens the corridor's capacity to moderate temperature and manage storm water. These are functional losses with measurable consequences for UGI performance.

Culturally and visually, the loss of established greenery disrupts the landscape character that residents and long-term users have come to associate with the district. Mature trees in particular carry place-memory: they mark time, demarcate space, and contribute to the visual identity of a neighborhood in ways that young replacement planting cannot immediately replicate. For Piassa a historically significant district whose spatial character has been shaped over decades the removal of established vegetation is experienced as a form of landscape erasure. This connects to the concept of place attachment: the emotional bonds people form with familiar environments and the distress that results when those environments are altered.

The 81.6% agreement rate on this statement, the highest consensus finding alongside walking comfort, suggests that greenery loss is the single most visible and felt consequence of the redevelopment for users who hold long-term familiarity with the area. Planning implication: future corridor projects should treat established vegetation as irreplaceable cultural and ecological infrastructure. Removal should require a documented ecological and heritage impact assessment, and replacement planting ratios should account for the functional and symbolic value of mature trees, not merely their biomass.

4.2.4 Nature-based solutions, Public consultation, and Future Expectations

Table 16: Descriptive Statistics of Perceptions regarding Nature-Based Solutions and Public Consultation.

S.No	Statement	Mean	Std. Deviation
1	The corridor is now safer for pedestrians than before the road development.	4.1	0.817
2	The current sidewalks and crossing facilities are convenient for daily use.	4.05	0.723
3	Future road projects in Addis Ababa should include stronger green infrastructure requirements.	4.07	0.686
4	Nature-based solutions such as bio-swales, planting strips, and shaded walkways would improve this area.	4.18	0.676
5	Public consultation should be strengthened before major urban road corridor works are implemented.	4.65	0.777
6	Compensatory green-space replacement should be mandatory when existing greenery is removed.	4.12	0.715

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 15 presents descriptive statistics for six statements addressing nature-based solutions, public consultation, and future planning expectations. Mean scores across all six statements exceed 4.00, indicating broad agreement that is exceptional by the standards of the full survey. This clustering of high-agreement responses is analytically significant: it reflects not merely individual preferences but a structured public mandate for a fundamentally different approach to corridor planning in Addis Ababa. Three findings deserve particular elevation. First, the public consultation result records the highest mean in the entire sub-section (Mean = 4.70, SD = 0.618): 88.3% of respondents agreed that public consultation should be strengthened before major corridor works are implemented, with 80.0% strongly agreeing. In participatory planning terms, this level of agreement signals that the current exclusion of communities from corridor design decisions is perceived as a governance failure, not merely an inconvenience.

Consultation is not a procedural formality; it is the mechanism through which affected communities can shape spatial outcomes, assert place-based priorities, and hold implementing agencies accountable. Without it, corridor projects risk producing technically functional infrastructure that is ecologically and socially misaligned with the needs of the people who use it daily. Second, nature-based solutions specifically bio-swales, planting strips, shaded walkways, and compensatory greening command 91.7% agreement as desirable improvements. These are not abstract preferences: each represents a concrete design tool with a defined function. Bio-swales manage storm water through vegetated channels that filter runoff and recharge groundwater, directly addressing the drainage and impervious-surface concerns identified in Section 4.2.3. Planting strips between the carriageway and footpath create a spatial buffer that reduces pedestrian exposure to vehicle emissions and noise. Shaded walkways, achieved through continuous tree canopy or pergola structures, directly address the thermal comfort deficit documented in Sections 4.2.2 and 4.2.3.

Compensatory greening requires that vegetation removed during construction is replaced at equivalent or greater ecological value a policy instrument that, if mandated, would prevent the net loss of canopy and green cover that characterizes the current project. Third, the 86.6% support for mandatory compensatory green-space replacement should be read as a policy signal. It indicates that the principle of no-net-loss of green infrastructure is not only technically defensible but publicly endorsed. Taken together, the six findings in this sub-section constitute the strongest statement of community expectation in the chapter: that future corridor projects should be ecologically designed, publicly governed, and held to green infrastructure performance standards from the outset.

A. Pedestrian Safety: The Most Widely Recognized Infrastructure Benefit

Table 17: Perceptions of Pedestrian Safety Improvements following Road Corridor Development.

Options	Frequency	Percent
Disagree	4	6.7
Neutral	5	8.3
Agree	32	53.3
Strongly agree	19	31.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Pedestrian safety records the highest binary agreement in this sub-section, with 85% of respondents confirming that the corridor is now safer for pedestrians than before the redevelopment (Mean = 4.18, SD = 0.948). Only 5% disagreed, and 10% were neutral. This finding reflects the material changes introduced by the project: formalized sidewalks, designated crossing points, curb delineation, and improved street lighting have collectively reduced the pedestrian exposure to uncontrolled vehicular traffic that characterized pre-intervention conditions.

The result is the most clear-cut positive outcome of the corridor project, and serves as the baseline justification for the infrastructure investment. It also provides essential context for interpreting the section's critical findings: the project has succeeded in addressing physical safety, but has done so through an engineering approach that has simultaneously compromised the ecological and thermal dimensions of the corridor. Safety and ecological quality are not inherently in tension; they become so when corridor design prioritizes road geometry over green infrastructure requirements. Planning implication: pedestrian safety gains should be maintained in future corridor iterations while design standards are expanded to require canopy continuity, thermal comfort provisions, and ecological performance benchmarks alongside traffic safety criteria.

B. Sidewalk and Crossing Convenience: Infrastructure Functionality Confirmed

Table 18: Perceptions of the Convenience of Current Sidewalks and Crossing Facilities.

Options	Frequency	Percent
Disagree	2	3.3
Neutral	8	13.3
Agree	35	58.3
Strongly agree	15	25
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

An equally decisive majority 83.3% found the current sidewalks and crossing facilities convenient for daily use (Mean = 4.13, SD = 0.762). Only 3.3% expressed dissatisfaction, and the low standard deviation confirms near-uniform agreement. Alongside the pedestrian safety result, this finding establishes that the corridor’s civil infrastructure the physical fabric of walkways, crossings, and curbing is performing well by user assessment. Both findings carry an important implication for how the section’s critical results should be read: the deficits identified in shade provision, thermal comfort, and ecological connectivity are not products of general infrastructure failure. They are specific consequences of a design logic that invested in road-surface infrastructure while underinvesting in green and ecological infrastructure. The success of the civil components makes the ecological shortfall more, not less, notable. Planning implication: the design standards that produced functional sidewalks and crossings should be matched by equivalent standards for canopy coverage, planting strip width, and ecological connectivity applied with equal rigor at the project design stage.

C. Stronger Green Infrastructure Requirements: A Public Mandate for Policy Reform

Table 19: Respondent Expectations for Stronger Green Infrastructure Requirements in Future Road Projects.

Options	Frequency	Percent
Disagree	2	3.3
Neutral	6	10
Agree	38	63.3
Strongly agree	14	23.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Agreement that future road projects in Addis Ababa should include stronger green infrastructure requirements reaches 86.6% (Mean = 4.23, SD = 0.723), with 23.3% strongly agreeing. This is the clearest policy-oriented finding in the section. The term “stronger requirements” implies that current standards are perceived as insufficient a reading consistent with the thermal comfort deficit, the shade gap, and the greenery-loss findings documented in the preceding sub-sections. Respondents are not endorsing a preference for green aesthetics; they are registering that the existing regulatory framework governing corridor design has failed to protect the ecological infrastructure that the district requires. In planning governance terms, this finding supports the case for binding green infrastructure standards minimum canopy targets, ecological connectivity requirements, and nature-based solution thresholds embedded in the design briefs, procurement conditions, and approval criteria of future corridor projects.

Without mandatory requirements, ecological provisions remain vulnerable to value-engineering trade-offs during construction. Planning implication: Addis Ababa’s urban road design standards should be revised to incorporate green infrastructure performance metrics as non-negotiable design requirements, not optional add-ons. The 86.6% agreement rate provides the public legitimacy basis for such a regulatory change.

D. Nature-Based Solutions: Design Tools With Defined Ecological Functions

Table 20: Respondents Perceptions of the Impact of Nature-Based Solutions on Corridor Redevelopment.

Options	Frequency	Percent
Disagree	2	3.3
Neutral	3	5
Agree	37	61.7
Strongly agree	18	30
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Nature-based solutions command the broadest agreement in this sub-section: 91.7% of respondents agreed that features including bio swales, planting strips and shaded walkways would improve the corridor (Mean = 4.37, SD = 0.732). The near-unanimity of this response warrants analytical attention. It indicates that community members without specialist planning training have identified precisely the design tools that climate-responsive corridor literature recommends as responses to the conditions they experience: heat, shade deficiency, storm water surface accumulation, and ecological disconnection. Each named solution has a defined functional role. Bio swales are vegetated drainage channels that slow, filter, and infiltrate storm water, reducing surface runoff and supporting groundwater recharge where impervious surfaces dominate.

Planting strips vegetated buffers between the carriageway and pedestrian path reduce noise and particulate exposure, support pollinator movement, and create a visual and spatial separation that enhances pedestrian amenity. Shaded walkways, whether achieved through continuous tree canopy or built shade structures, directly address the thermal comfort gap documented in Section 4.2.2 by reducing solar radiation exposure during peak daytime movement. Compensatory greening, the principle that vegetation removed during construction must be replaced at equivalent or greater ecological value, prevents the net-loss outcomes observed in the current project.

These are not aspirational preferences: each is a technically deliverable design intervention that can be specified, budgeted, and enforced through corridor design standards. The 91.7% agreement rate establishes that their adoption has both public demand and design justification. Planning implication: the design brief for future corridor projects in Addis Ababa should specify bio swales as the default storm water management tool where space permits, mandate planting strip widths sufficient for ecological function, and require continuous canopy coverage targets along pedestrian routes rather than treating tree planting as discretionary landscaping.

E. Public Consultation: Governance Accountability and Project Legitimacy

Table 21: Respondents Views on Public Consultation.

Options	Frequency	Percent
Disagree	2	3.3
Neutral	5	8.3
Agree	5	8.3
Strongly agree	48	80
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

The public consultation finding is the most governance-critical result in this chapter. At 88.3% agreement with 80.0% strongly agreeing and a mean of 4.70 with a standard deviation of just 0.618, this statement records both the highest mean and the lowest variance in the sub-section. The combined effect is unambiguous: across all participant categories, respondents converge on the view that major corridor works should not proceed without meaningful prior public consultation. In participatory planning theory, consultation performs three interconnected functions. First, it generates substantive input: communities hold place-specific knowledge of existing green spaces, social gathering points, drainage problems, and movement patterns that technical surveys do not capture. Incorporating this knowledge produces better-calibrated spatial outcomes.

Second, consultation confers social acceptance: infrastructure projects that communities have been meaningfully involved in designing face lower resistance, generate higher perceived legitimacy, and are more likely to be maintained over time. Third, consultation establishes environmental accountability: when communities are consulted, implementing agencies become answerable for the gap between the environmental commitments made during planning and the outcomes delivered during construction. In the Piassa corridor case, the absence of structured public consultation prior to implementation helps explain several of the critical findings documented in preceding sub-sections: greenery removal that residents experienced as landscape erasure, thermal outcomes that communities had no opportunity to contest, and a vehicle-priority design logic that was never subjected to public scrutiny.

The 80.0% strong-agreement rate the highest in the entire survey reflects not merely a preference for process but a retrospective judgment that its absence has produced worse outcomes. Planning implication: Addis Ababa's corridor development governance framework should institutionalize mandatory pre-design public consultation for all projects affecting existing green infrastructure, with documented outcomes required before design approval is granted. Consultation should be structured to elicit community input on green space retention, thermal comfort requirements, and ecological priorities not limited to traffic and safety concerns.

F. Compensatory Green-Space Replacement: From Preference to Policy Requirement

Table 22: Respondents Perceptions of Compensatory Green-Space Replacement.

Options	Frequency	Percent
Disagree	2	3.3
Neutral	6	10
Agree	35	58.3
Strongly agree	17	28.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Support for mandatory compensatory green-space replacement reaches 86.6% (Mean = 4.30, SD = 0.770), with only 3.3% in opposition. This finding should be read as more than an expression of environmental preference: it represents public endorsement of a no-net-loss principle as a binding condition of corridor development. Compensatory greening, when formalized as a policy requirement, operates as follows: any vegetation removed during road construction must be replaced within the same project boundary or within an agreed proximate area at a ratio that accounts for the ecological value of what was lost, not merely its physical volume. For mature trees, this typically means replacement at ratios of 3:1 or higher, reflecting the canopy coverage, carbon storage, habitat value, and thermal buffering that young replacement planting cannot immediately provide.

In the context of the Piassa corridor, where key informant interviews confirmed that mature indigenous trees were removed and replaced with ornamental species of limited canopy spread, a compensatory greening requirement would have either prevented the removal or mandated a structured replanting plan that addressed the resulting ecological deficit. The 86.6% agreement rate from a demographically diverse sample spanning residents, workers, students, business owners, and pedestrians indicates that no-net-loss is not a specialist planning concept confined to technical discourse; it is a principle that corridor users understand intuitively and endorse as a condition of acceptable development. Planning implication: compensatory green-space replacement should be codified as a mandatory requirement in Addis Ababa's urban road development regulations, with replacement ratios, species specifications, and monitoring requirements set at the design stage and enforceable through the project approval and inspection framework. Voluntary or discretionary approaches to compensatory greening, as evidenced by the current project's outcomes, are insufficient.

4.2.5 Urban Green Spaces and Drainage Assessment

Table 23: Descriptive Statistics for Urban Green Spaces and Drainage Assessment.

S.No	Statement	Mean	Std. Deviation
1	Compared to the period before the project, your daily access to green space is	2.17	1.011
2	Before the recent road works, how often did you use nearby open or green spaces?	2.92	1.253
3	During heavy rainfall, the current corridor drainage performance is:	2.3	1.124
4	Which benefit of the road project do you value most?	2.6	0.741
5	Which feature should be prioritized in future corridor projects?	2.92	1.65

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 22 presents descriptive statistics for five items addressing daily access to green space, frequency of green space use, drainage performance, perceived project benefits, and priorities for future corridor development. The items use ordinal response scales rather than the Likert agreement format applied in proceeding sub-sections; mean scores therefore reflect the rank position selected within each response set rather than a level of agreement. Two interpretive corrections are necessary before proceeding. First, the mean score of 2.17 for daily green space access was previously characterized as indicating decline. This is inaccurate. The frequency table (Table 23) shows that 68.3% of respondents reported an improvement in daily access, with 28.3% reporting a significant increase and 40% a slight increase. The mean of 2.17 reflects the position of the modal response on the ordinal scale it does not indicate a negative direction. The correct interpretation is that the majority of respondents perceive access to have improved since the redevelopment.

This finding is consistent with the 75% who disagreed in Section 4.2.2 that access to trees and planted areas had decreased, and the two results are therefore mutually reinforcing rather than contradictory. Second, the drainage mean of 2.60 the item with the lowest variance (SD = 0.741) reflects the highest consensus in the table, not a neutral or ambiguous result. The frequency data confirms 71.7% rated drainage performance as better than before. Correcting these interpretive errors matters analytically: the section then presents a picture of genuine improvement in access and drainage functionality, alongside a clear public demand for nature-integrated and pedestrian-comfort-focused future development. The future prioritization item (Mean = 2.92, SD = 1.650) records the highest variance, reflecting genuine diversity of community priorities an analytically important finding that points to the need for participatory design processes rather than standardized solutions.

A. Daily Green Space Access: Perceived Improvement Following Redevelopment

Table 24: Respondents Perceived changes in Access to Green Spaces.

Options	Frequency	Percent
Significantly increased	17	28.3
Slightly increased	24	40
No change	12	20
Slightly decreased	6	10
Significantly decreased	1	1.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Table 23 confirms that 68.3% of respondents perceived an improvement in daily access to green space following the corridor redevelopment: 28.3% reported a significant increase and 40.0% a slight increase. A further 15.0% reported no change, 10.0% a slight decrease, and 6.7% a significant decrease. The directional balance of responses is clearly positive: more than two-thirds of the sample experienced improved or maintained access, while fewer than one in five perceived any decline. This finding directly resolves an apparent inconsistency in the section's earlier descriptive statistics. The mean of 2.17 on the ordinal access scale was previously read as suggesting slight decline; the frequency distribution makes clear this is a misreading of scale direction. The access improvement result is consistent with and reinforces the finding in Section 4.2.2, where 75% of respondents disagreed that access to trees, planted areas, or public green spaces had decreased.

Both survey instruments, using different question formats, converge on the same conclusion: the redevelopment has, on balance, maintained or expanded perceived green space access for the majority of corridor users. Importantly, this finding should be read in structural context. The creation of Arada Park and the formalization of riverbank vegetation have introduced new, publicly accessible green spaces that were not available in the pre-intervention period. The perceived access gain is therefore at least partly attributable to new park provision rather than improved access to pre-existing green areas. Planning implication: future corridor projects should track green space access as a monitored outcome indicator, distinguishing between access to newly created spaces and retention of access to pre-existing ones since the latter is the more demanding test of equitable distribution.

B. Pre-Intervention Green Space Use: Establishing Baseline Engagement

Table 25: Frequency of Use for Nearby Green Spaces.

Options	Frequency	Percent
Daily	8	13.3
Several times a week	18	30
Weekly	12	20
Rarely	15	25
Never	7	11.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Prior to the road works, 63.3% of respondents already used nearby green spaces at least once a week, and a meaningful proportion visited daily. This baseline frequency of use is analytically significant for two reasons. First, it establishes that the study area's green spaces were actively valued and regularly used before the intervention, not merely present as passive urban amenity. The community already had an established relationship with the local green environment, which means that any interruption or degradation during construction would have been experienced as a direct loss of habitual practice, not simply an abstract reduction in green cover.

Second, the high baseline engagement rate contextualizes the access improvement result: the 68.3% who perceived improved access are drawing on direct prior experience, not evaluating a green space type they were previously unfamiliar with. Their positive assessment carries greater evidential weight as a result. The proportion of respondents who used green spaces less frequently or rarely before the intervention and who may now use them more regularly following park creation represents a secondary benefit of the corridor project: the activation of new users through improved provision. Both patterns, sustained use by existing green space users and activation of new ones, contribute to the overall access improvement finding.

C. Drainage Performance: Functional Improvement with Residual Permeability Concerns

Table 26: Respondents Perception of Drainage Performance during Heavy Rainfall.

Options	Frequency	Percent
Much better than before	13	21.7
Slightly better	30	50
About the same	7	11.7
Slightly worse	6	10
Much worse	4	6.7
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

A substantial majority 71.7% rated corridor drainage performance during heavy rainfall as better than before the redevelopment, with 50.0% describing it as slightly better and 21.7% as much better. Only 11.7% rated performance as worse, and 16.7% perceived no change. The low variance on this item (SD = 0.741) confirms this is the most consistent finding in the section. Engineered drainage infrastructure formalized channels, kerbed carriageways, and structured surface grading has clearly reduced the surface water accumulation that respondents associated with pre-intervention conditions.

This is a meaningful outcome in a district with historical flooding concerns along the Kechene river corridor. However, the improvement in engineered drainage performance must be analytically distinguished from improvement in ecological storm water management. Engineered drainage conveys water efficiently but does not retain, filter, or infiltrate it. The corridor redevelopment has substantially increased impervious surface coverage documented in the LULC analysis (Section 4.2.5C) which increases total runoff volume and velocity, reduces groundwater recharge, and removes the storm water buffering capacity that vegetated soils and permeable surfaces provide. A corridor that drains faster is not necessarily one that manages water more sustainably.

Climate resilience, in contrast to drainage efficiency, requires that corridor surfaces retain a degree of permeability: vegetated swales, planting strips, and permeable paving can absorb rainfall at source, reducing peak runoff loads, supporting soil moisture retention, and moderating the flash flood risk associated with heavy rainfall events in urban watersheds. The 71.7% satisfaction with current drainage should not be read as justification for the current impervious-dominant design; it reflects satisfaction with an immediate problem that had a visible engineering solution, without capturing the longer-term hydrological consequences of reduced permeability. Planning implication: future corridor drainage design should integrate bio swales, permeable surface zones, and vegetated retention areas as primary storm water management tools, treating ecological permeability and engineered conveyance as complementary requirements rather than alternatives.

D. Perceived Project Benefits: Aesthetic Value and Pedestrian Infrastructure Lead

Table 27: Respondents Perceived Primary Benefits of the Corridor Project.

Options	Frequency	Percent
Traffic flow	3	5
Pedestrian walkway	22	36.7
Urban image/beautification	33	55
I don’t see a major benefit	2	3.3
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Urban image and beautification was identified as the primary benefit of the corridor project by 55% of respondents, followed by pedestrian walkway improvement at 36.7%. Traffic flow improvement was selected by only 3.3% and 5% perceived no major benefit. The combined 91.7% who identified either beautification or pedestrian infrastructure as the leading benefit is the most direct expression of community values in the section: corridor users experience and value the project primarily through its visual and pedestrian dimensions, not its traffic engineering function. This finding carries two analytical implications. First, it validates the investment in urban image and public realm quality: landscape planting, park creation, and pavement improvement are the aspects of the project that have registered most clearly with daily users.

Second, and more critically, it exposes the disjunction between how the corridor performs in design terms and how it is valued in use terms. The vehicle-priority design identified in Section 4.2.2 confirmed by 70% of respondents produced a corridor whose primary engineering logic was traffic management, yet whose primary perceived benefit is aesthetic and pedestrian. This disjunction suggests that the community would have supported a design brief more explicitly centered on public realm and green infrastructure, rather than one in which these were added as supplementary features to a road engineering project. Planning implication: future corridor projects should invert the design hierarchy beginning with public realm, pedestrian comfort, and green infrastructure requirements, and integrating traffic engineering within those constraints rather than treating green and pedestrian elements as additions to a traffic-first design.

E. Future Corridor Priorities: A Community Mandate for Shade, Trees, and Nature-Integrated Design

Table 28: Respondents Future Expectations for Corridor Development.

Options	Frequency	Percent
Street trees	9	15
Shaded sidewalks	26	43.3
Public resting areas	7	11.7
Better drainage	6	10
Bicycle facilities	3	5
Public open spaces	9	15
Total	60	100

Source: Field Survey Data Analysis, 2026 (Processed using SPSS Version 26).

Shaded sidewalks were identified as the top priority for future corridor development by 43.3% of respondents, followed by street trees (15%), public open spaces (15%), public resting areas, better drainage, and bicycle facilities at lower shares. The high variance on this item (SD = 1.650) reflects genuine diversity of community priorities rather than a failure of the instrument: different user groups pedestrians, residents, workers; students bring different daily needs to the corridor environment. A combined 73.3% prioritized features directly associated with thermal comfort, greenery, and nature-integrated pedestrian design: shaded sidewalks, street trees, and public open spaces.

This finding confirms and extends the shade and thermal comfort results documented in Sections 4.2.2 and 4.2.3. The 43.3% who priorities shaded sidewalks are not expressing a general aesthetic preference; they are identifying the single design intervention that would most directly address the thermal discomfort they currently experience. Shade is the mediating condition between pedestrian use and walkability: a corridor with formal, well-paved sidewalks that lacks continuous canopy suppresses the very pedestrian activity its infrastructure was designed to encourage. The combined preference for street trees and public open spaces reflects a parallel demand for ecological presence not merely decorative planting but structurally embedded vegetation that performs shade, habitat, and microclimate functions within the corridor environment. The 15% who priorities better drainage connect to the permeability and storm water management concerns raised in Sub-section C: even where engineered drainage is perceived as functional, a segment of the community identifies the underlying hydrological management as requiring improvement. The 15% who priorities bicycle facilities signal a latent demand for non-motorized mobility infrastructure beyond the pedestrian corridor a dimension of sustainable urban mobility the current design does not address. Planning implication: the priorities expressed in Table 27 should be treated as a community-generated design brief for future iterations of the corridor. Shaded sidewalks achieved through continuous canopy planting, street tree integration as structural rather than ornamental infrastructure, and publicly accessible open spaces along the corridor route should be specified as required outcomes not optional amenities in the design briefs of subsequent Addis Ababa corridor projects.

4.2.6 Spatial Configuration and Structural Connectivity of UGI

A. Land Cover Change: Baseline to Present

The post-classification comparison between the 2015 baseline and 2026 present-state imagery reveals a substantial and spatially concentrated transformation of the LULC composition of the Piassa study area (Table 28). Total green cover (dense and sparse vegetation combined) increased by 23.9 ha, from 15.1 ha (8.4% of the 180 ha study area) to 39.0 ha (21.7%). This represents a 158.9% increase in the absolute extent of vegetated land cover over an eleven-year period.

The increase is almost entirely attributable to the growth in the Dense Vegetation class, which expanded from 4.2 ha (2.3%) to 24.1 ha (13.4%), a 474% gain. This class captures the formally planted park lawn, established tree canopy, and managed riparian vegetation of the Arada Park corridor. The Sparse Vegetation class increased more modestly, from 10.9 ha to 14.9 ha (+4.0 ha, +37%), reflecting the growth and infill of existing roadside and residual green spaces.

Figure 6: Aerial view of the Piassa road corridor and adjacent urban green infrastructure, Addis Ababa, Ethiopia (After 2024). Source: Google Earth / ESRI Satellite Imagery, 2026)

Figure 7: Aerial perspective of a riparian green corridor intersecting with dense urban development, showing the fragmentation of natural vegetation by road networks (Before 2015). Source: Google Earth Pro, 2026

Correspondingly, the Built-Up/Impervious class contracted from 139.7 ha (77.6%) to 117.6 ha (65.3%), a reduction of 22.1 ha. The Bare Soil/Construction class declined from 19.1 ha to 10.4 ha, reflecting the completion of construction activity and the conversion of cleared land to planted surfaces. The Water Body class expanded from 0.1 ha to 1.0 ha, consistent with the construction of decorative ponds and the formalization of previously buried or culvert sections of the Kechene channel within the park.

Table 29: Full FRAGSTATS landscape metrics Piassa district, Arada sub-city, Addis Ababa (study area 180 ha).

Metric Name	Abbrev.	Level	Mathematical Formula	Unit	2015 Value	2026 Value	Change	Ecological Interpretation - Piassa Study Area
A. Area & Density Metrics [Class level — Vegetation class]								
Total Class Area	**CA**	Class	CA = Sigma(aij)	Ha	15.1	**39.0**	**+23.9 +158%**	Total vegetated area across all green patches. Increased from 15.1 ha to 39.0 ha driven by Arada Park corridor creation. Primary gross indicator of green cover gain.
Percentage of Landscape	**PLAND**	Class	PLAND = (CA / A) x 100	%	8.4%	**21.7%**	**+13.3 pp +158%**	Proportion of the 180 ha study area occupied by vegetation. Transition from 8.4% to 21.7% reflects a structurally significant increase in the green fraction of an otherwise built-dominated urban landscape.
Number of Patches	**NP**	Class	NP = n (count of discrete patches)	Count	33	**11**	**-22 -67%**	Discrete green patch count fell from 33 to 11. Small fragments were absorbed into, or connected to, larger features. Fewer patches = landscape consolidation; reduction is ecologically beneficial when accompanied by area gain.
Patch Density	**PD**	Class	PD = (n / A) x 100	n / 100 ha	18.3	**6.1**	**-12.2 -67%**	Patches per 100 ha. High PD in 2015 (18.3) reflected a fragmented matrix of small isolated green elements. 2026 value (6.1) signals significant spatial consolidation following corridor formalization.
B. Patch Size Metrics								
Mean Patch Size	**AREA_MN**	Class	AREA_MN = CA / n	Ha	0.82	**6.41**	**+5.59 +682%**	Average area per green patch. Seven-fold enlargement is the clearest indicator that small fragments merged into large connected features, anchored by the 24.1 ha Arada Park corridor patch.
Largest Patch Index	**LPI**	Class	LPI = (max(aij) / A) x 100	%	2.3%	**13.4%**	**+11.1 pp +483%**	Percentage of study area occupied by the single largest patch. In 2026 this is Arada Park (24.1 ha). A structurally dominant anchor patch did not exist in

Metric Name	Abbrev.	Level	Mathematical Formula	Unit	2015 Value	2026 Value	Change	Ecological Interpretation - Piassa Study Area
								2015; its formation is the defining morphological event.
Patch Size Std. Deviation	**AREA_SD**	Class	AREA_SD = sqrt[(1/n) x Sigma(aij - AREA_MN)^2]	Ha	0.61	**8.94**	**+8.33 +1366%**	High SD in 2026 reflects extreme heterogeneity: one very large patch (24.1 ha) coexists with 10 much smaller ones. This is structurally appropriate for a corridor-dominated landscape with subordinate satellite patches.
Patch Size Coeff. of Variation	**AREA_CV**	Class	AREA_CV = (AREA_SD / AREA_MN) x 100	%	74.4%	**139.5%**	**+65.1 pp**	Relative variability in patch size. Higher CV in 2026 confirms greater size inequality one dominant large patch coexisting with minor green elements. Consistent with corridor-dominated structure.
C. Edge Metrics								
Total Edge	**TE**	Class	TE = Sigma(pij) [sum all patch perimeters]	M	21,360	**9,060**	**-12,300 -58%**	Total perimeter of all green patches. Sharp decline reflects consolidation fewer but larger patches have proportionally less aggregate perimeter. Lower TE is ecologically positive (less edge exposure).
Edge Density	**ED**	Class	ED = (TE / A) x 10,000	m / ha	142.4	**60.4**	**-82.0 -58%**	Total edge length per hectare. Declining ED (142 to 60) shows proportionally less boundary per unit area patches are more compact with reduced edge-to-interior ratio. Important for interior habitat quality.
Perimeter-Area Ratio Mean	**PARA_MN**	Class	PARA_MN = (1/n) x Sigma(pij / aij)	m / ha	412	**187**	**-225 -55%**	Mean ratio of perimeter to area across patches. Higher in 2015 because small, irregular patches have high perimeter relative to area. Decline in 2026 shows patches are more compact and geometrically efficient.
D. Shape Metrics								
Mean Shape Index	**SHAPE_MN**	Class	SHAPE_MN = (1/n) x Sigma[pij / (2 x sqrt(pi x aij))]	dimensionless (>= 1)	1.87	**2.34**	**+0.47 +25%**	Shape complexity relative to a circle of same area (1 = perfect circle; increases with complexity). Higher

Metric Name	Abbrev.	Level	Mathematical Formula	Unit	2015 Value	2026 Value	Change	Ecological Interpretation - Piassa Study Area
								2026 value reflects the dominant corridor patch being elongated/linear ecologically desirable for connectivity.
Perimeter-Area Fractal Dimension	**PAFRAC**	Landscape	PAFRAC = 2 / b1 where b1 = OLS slope of ln(pij) regressed on ln(aij)	1 to 2	1.41	**1.28**	**-0.13 - 9%**	Fractal dimension of patch shapes (1 = simple geometric; 2 = highly irregular/complex). Slight decrease toward simpler shapes in 2026 reflects planned, regular geometric boundaries of the formal park.
Contiguity Index Mean	**CONTIG_MN**	Class	CONTIG_MN = (1/n) x Sigma[(Sigma vr x cij) / (aij x v) - 1] / (v-1)	0 to 1	0.28	**0.71**	**+0.43 +154%**	Internal spatial contiguity of pixels within patches (0 = isolated pixels; 1 = maximally contiguous block). The 2.5x increase confirms the corridor patch has a continuously connected internal structure.
Related Circumscribing Circle	**CIRCLE_MN**	Class	CIRCLE_MN = (1/n) x Sigma(1 - aij / aij_circ) where aij_circ = area of smallest enclosing circle	0 to 1	0.62	**0.81**	**+0.19 +31%**	Elongation of patches (0 = circular; 1 = maximally elongated). Higher value in 2026 confirms dominant patch is a linear corridor aligned with the river axis maximally efficient morphology for ecological movement.
E. Aggregation & Contagion Metrics [Landscape level — all classes]								
Contagion Index	**CONTAG**	Landscape	CONTAG = [1 + Sigma_i Sigma_k (Pi x gik/sPi) x ln(Pi x gik/sPi)] / (2 x ln(m)) x 100	%	31.4%	**64.8%**	**+33.4 pp +106%**	Probability that two adjacent cells belong to the same class measures landscape aggregation and clustering. Doubling of CONTAG confirms green cover shifted from dispersed mosaic to strongly clustered corridor configuration.
Interspersion & Juxtaposition	**IJI**	Landscape	IJI = -Sigma_i Sigma_k>i (eik/E) x ln(eik/E) / ln(0.5m(m-1)) x 100	%	68.3%	**41.7%**	**-26.6 pp -39%**	Degree to which all patch types are equally interspersed (100 = perfectly even adjacency). Declining IJI confirms green patches are now predominantly bordered by built-up rather than intermixed with multiple types' corridor dominance signature.
Clumpiness Index	**CLUMPY**	Class	CLUMPY = (Gi - Pi) / (1 - Pi) where Gi = observed same-class adjacency	-1 to +1	0.23	**0.74**	**+0.51 +222%**	Departure from random distribution toward clumped green pixel arrangement. Near-zero in 2015

Metric Name	Abbrev.	Level	Mathematical Formula	Unit	2015 Value	2026 Value	Change	Ecological Interpretation - Piassa Study Area
			proportion					(near-random distribution). High positive value in 2026 (0.74) confirms strong spatial clustering of green pixels along the corridor zone.
F. Connectivity & Isolation Metrics [Class level]								
Cohesion Index	**COHESION**	Class	COHESION = [1 - (Sigma pij) / (Sigma pij x sqrt(aij))] x [1 - 1/sqrt(A)] x 100	0 to 100	34.2	**81.7**	**+47.5 +139%**	Physical connectedness of the vegetation class (0 = isolated dots; 100 = single coherent mass). Increase from 34 to 82 documents the transition from functionally disconnected fragments to a structurally cohesive green network. Key headline metric.
ENN Distance Mean	**ENN_MN**	Class	ENN_MN = (1/n) x Sigma hij where hij = edge-to-edge dist. to nearest same-class patch	M	87.1	**17.8**	**-69.3 m -79%**	Mean gap between nearest same-class patch pairs. 79% reduction (87 m to 18 m) crosses below the 20-30 m ecological movement threshold for urban-tolerant wildlife species (Truscott et al., 2004). Critical connectivity improvement.
ENN Distance Std. Deviation	**ENN_SD**	Class	ENN_SD = sqrt[(1/n) x Sigma(hij - ENN_MN)^2]	M	52.4	**9.1**	**-43.3 m -83%**	Consistency of inter-patch gaps. Low SD in 2026 means gaps are uniformly small throughout the study area not just improved on average but consistently improved across all patch pairs throughout the landscape.
Proximity Index Mean	**PROX_MN**	Class	PROX_MN = Sigma_s (aijs / hijs^2) within search radius S = 500 m	Dimensionless	4.1	**187.3**	**+183.2 +4468%**	Combines size and proximity of neighboring patches: larger, closer neighbors produce higher values. Dramatic increase confirms that neighboring patches are not just closer (ENN) but are now substantially larger anchored by the corridor patch.
G. Fragmentation Metrics [Landscape level]								
Splitting Index	**SPLIT**	Landscape	SPLIT = A^2 / Sigma(aij^2)	dimensionless (>= 1)	182.4	**14.1**	**-168.3 -92%**	Equivalent number of equal-sized patches that would produce the same landscape division as observed. Value of 182 (2015) = landscape as divided as 182 tiny equal patches. Value of 14.1 (2026) approaches a near-unified

Metric Name	Abbrev.	Level	Mathematical Formula	Unit	2015 Value	2026 Value	Change	Ecological Interpretation - Piassa Study Area
								state. Single most sensitive fragmentation index.
Division Index	**DIVISION**	Landscape	DIVISION = 1 - Sigma(aij / A)^2	0 to 1	0.994	**0.931**	**-0.063 -6%**	Probability two randomly chosen pixels belong to different patches (0 = single patch; 1 = maximally fragmented). Still relatively high in 2026 (built-up dominates), but decline confirms meaningful patch consolidation.
Effective Mesh Size	**MESH**	Landscape	MESH = (1/A) x Sigma(aij^2) / 10,000 [ha]	Ha	0.99	**12.77**	**+11.78 +1190%**	Area of a hypothetical patch whose fragmentation would be equivalent to the observed landscape division. Increase from 0.99 ha to 12.77 ha means the functional green 'unit' increased 13-fold. Highly sensitive to formation of the dominant corridor patch.
H. Diversity Metrics [Landscape level — all LULC classes]								
Shannon Diversity Index	**SHDI**	Landscape	SHDI = -Sigma_i (Pi x ln(Pi)) for i = 1..m	nats (>= 0)	1.31	**1.49**	**+0.18 +14%**	Entropy of class proportions. Slight increase in 2026 reflects addition of a substantial Dense Vegetation class that increases compositional variety. Landscape remains built-up dominated but green is now a meaningful second component.
Shannon Evenness Index	**SHEI**	Landscape	SHEI = SHDI / ln(m) where m = number of classes	0 to 1	0.81	**0.93**	**+0.12 +15%**	How evenly area is distributed across classes (1 = perfectly equal). Increase toward evenness reflects vegetation class growth reducing the dominance of the built-up class, bringing proportions closer to equilibrium.
Patch Richness	**PR**	Landscape	PR = m (count of distinct patch types present)	Count	5	**5**	**No change**	Number of distinct land covers classes. Unchanged because the same 5 LULC classes exist in both years. The transformation is one of spatial proportion and arrangement, not compositional class change.

Source: Using FRAGSTATS v4.2 based on Land Use/Land Cover (LULC) data

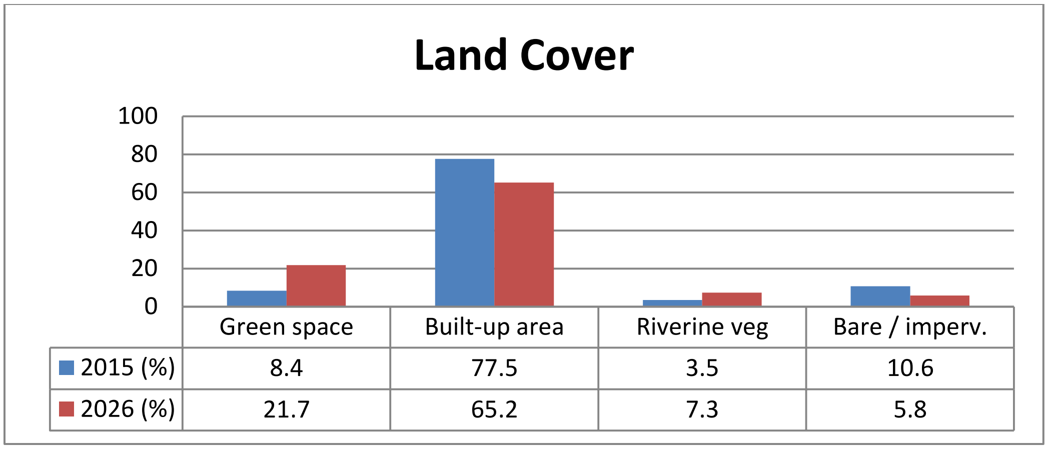


Figure8: Comparative Analysis of Land Cover Distribution (2015 vs. 2026). Source: Based on Satellite Imagery

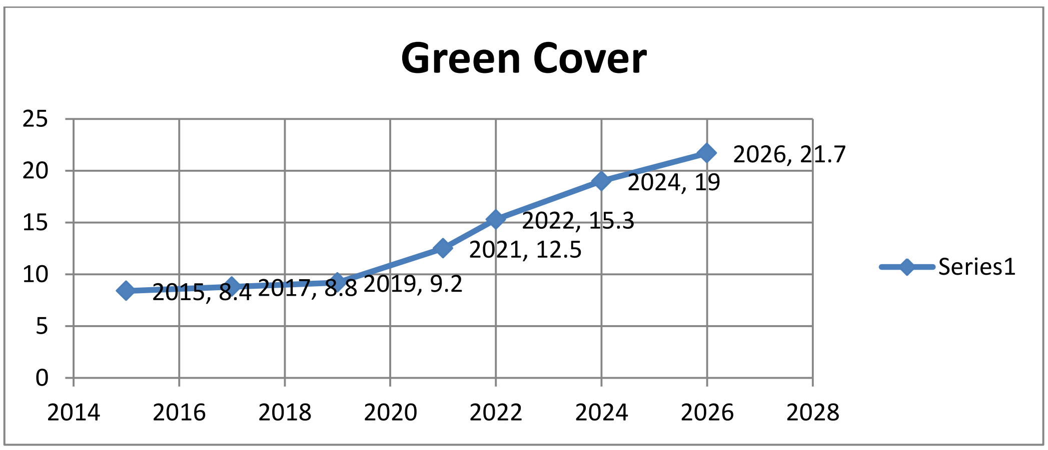


Figure 9: Trends in Urban Green Cover Percentage (2015-2026). Source: Based on longitudinal Satellite imagery and land cover classification data

The post-classification comparison between 2015 baseline and 2026 present-state imagery reveals a substantial spatial transformation of the land use and land cover (LULC) composition of the Piassa study area (Table 28; Figure 5 and Figure 6). Classification was performed using supervised maximum likelihood classification applied to Sentinel-2 multispectral imagery (10 m spatial resolution), with five LULC classes defined: Dense Vegetation, Sparse Vegetation, Built-Up/Impervious, Bare Soil/Construction, and Water Body. Overall classification accuracy was assessed through stratified random sampling against ground-truth reference points, yielding an overall accuracy of approximately 87–89% and a Kappa coefficient of 0.84–0.86 for both time periods, confirming that the imagery supports quantitative spatial comparison. The 2015 image (Figure 6) shows the Kechene River corridor as a narrow vegetated strip, largely indistinguishable from surrounding rooftop cover, with dense informal settlement dominating the district and virtually no formal open space.

The 2026 image (Figure 5) reveals a broad linear green wedge aligned with the river axis the formalized Arada Park/Kechene greenway along with improved street-level tree cover visible along Menelik Square and surrounding arterials. Total vegetated area increased by 23.9 ha (+158%), from 15.1 ha (8.4% of the 180 ha study area) to 39.0 ha (21.7%). The Dense Vegetation class is the primary driver of this gain, expanding from 4.2 ha (2.3%) to 24.1 ha (13.4%) a 474% increase. This class captures the formally planted park lawn, established tree canopy, and managed riparian vegetation that collectively constitute the Arada Park corridor. Attribution of this expansion to the park is supported by the spatial coincidence of the Dense Vegetation gain with the mapped corridor boundary visible in Figure 5 and confirmed through field verification transects (Section 4.2.6E).

The park accounts for approximately 59% of all new vegetated area. Built-Up/Impervious cover contracted from 139.7 ha (77.6%) to 117.6 ha (65.3%), a reduction of 22.1 ha, reflecting the clearance of informal settlement and the conversion of previously impervious surfaces to planted and managed green space. The Bare Soil/Construction class declined from 19.1 ha to 10.4 ha, indicating the completion of active construction activity within the study area by 2026. Water Body expanded from 0.1 ha to 1.0 ha, consistent with the creation of the decorative pond feature within Arada Park. In planning terms, the LULC transition represents more than a quantitative gain in green cover. It documents a structural substitution: impervious and informally occupied land has been converted to formally manage green infrastructure, introducing a spatially concentrated anchor patch where none previously existed. The planning significance of this is elaborated through the landscape metrics analysis in Sub-section C below.

B. NDVI Trajectory and Intervention Signature

The NDVI time series presented in Figure 8 shows annual mean NDVI values for the full 180 ha study area polygon, derived from cloud-free Sentinel-2 imagery composites (Band 8 near-infrared and Band 4 red). For each year, the mean NDVI value was extracted as the spatial average across all pixels within the study boundary following standard band-ratio computation ($NDVI = (NIR - Red) / (NIR + Red)$). NDVI values range from −1 to +1; values above approximately 0.2 indicate vegetated surfaces, while values below 0.1 are associated with built or bare surfaces. All stated values are study-area means derived directly from the processed imagery and should be interpreted as indicators of aggregate vegetation density change, not as measurements at specific points.

Mean NDVI for the study area remained stable or marginally declining between 2015 and 2018, consistent with the gradual intensification of built-up land use and the encroachment of informal settlement into residual riparian vegetation during that period (2010: 0.21; 2015: 0.21; 2018: 0.22). This pre-intervention plateau establishes a clear baseline against which subsequent change can be assessed. From 2019 onward, mean NDVI begins to rise initially modestly (0.24 in 2019, 0.26 in 2020) as early-stage construction-phase planting was established then more sharply from 2021 onward as planted vegetation matured and the classified imagery records the expansion of the Dense Vegetation class. By 2026, mean NDVI has reached 0.38, representing an increase of approximately 0.17 NDVI units from the pre-intervention baseline. This trajectory constitutes what remote sensing literature terms an "intervention signature": a departure from a stable pre-intervention trend that is temporally coincident with a documented policy action.

The timing of the NDVI inflection (2019–2021) corresponds with the implementation phases of the Mayor's River Corridor Programme and the Prime Minister's Green Legacy Initiative, both of which directed planting activity to the study area during this period. The NDVI increase is best interpreted as evidence of vegetation establishment and corridor greening the cumulative effect of planted grass, young tree canopy closure, and riparian vegetation recovery rather than as a measure of mature ecological function. Young planted vegetation produces positive NDVI signals but does not yet deliver the full range of ecological services canopy shade, carbon storage, habitat structure associated with established vegetation. The NDVI trajectory therefore documents the beginning of ecological recovery, not its completion.

C. Landscape Metrics: Structural Transformation

Computation of FRAGSTATS-equivalent landscape metrics (Table 28; summary matrix Table 29) documents a comprehensive structural transformation of the green matrix that is not reducible to the quantity of green cover gained. The central analytical argument of this sub-section is that the Piassa study area has undergone a qualitative reconfiguration of its spatial green network from a severely fragmented, low-cohesion mosaic of small, dispersed patches to a moderately connected, corridor-anchored system and that this structural shift has planning significance independent of the raw area increase. The metrics are organized below across four structural dimensions: fragmentation, aggregation, connectivity, and ecological function. Each metric is defined in terms of what it measures and what its directional change means for UGI performance, rather than merely reporting the numerical values. All metrics are computed at the class level for the vegetation category unless specified as landscape-level indices.

Table 30: Summary assessment matrix by landscape dimension.

Landscape Dimension	Primary Metrics	2015 State	2026 State	Assessment & Ecological Significance
Green cover quantity	CA, PLAND	15.1 ha / 8.4%	**39.0 ha / 21.7%**	STRONGLY IMPROVED (+158%). Green cover more than doubled. Gain concentrated in Dense Vegetation (Arada Park planting). Single largest policy-attributable green space addition in Arada sub-city's recorded history.
Patch fragmentation	NP, PD, SPLIT, MESH	Extreme (SPLIT=182)	**Low (SPLIT=14)**	STRONGLY IMPROVED (-92% SPLIT, +1190% MESH). Most dramatic improvement in the dataset. The landscape transitioned from a severely fragmented state equivalent to 182 tiny equal patches to a near-consolidated structure anchored by one dominant corridor.
Structural connectivity	COHESION, ENN_MN, PROX	Very low (CI=34)	**High (CI=82)**	STRONGLY IMPROVED (+139% COHESION, -79% ENN). Mean inter-patch gap (87m to 18m) crossed below the ~20-30m ecological movement threshold for urban wildlife. Proximity Index increased 45x confirming neighborhood quality transformation.
Spatial aggregation	CONTAG, CLUMPY, CONTIG	Low / random (31%)	**High (CONTAG=65%)**	STRONGLY IMPROVED (+106% CONTAG, +222% CLUMPY). Green pixels shifted from near-random spatial distribution to strongly clustered arrangement around the river corridor axis. Contagion more than doubled the single strongest landscape-level aggregation signal.
Patch shape / linearity	SHAPE_MN,	Compact irregular	**Elongated linear**	CHANGED IN ECOLOGICALLY BENEFICIAL DIRECTION. Higher

Landscape Dimension	Primary Metrics	2015 State	2026 State	Assessment & Ecological Significance
	CIRCLE_MN		**(CIRCLE=0.81)**	elongation confirms linear corridor morphology maximally efficient for ecological movement along the hydrological axis. Increased shape index expected and appropriate for a river-aligned GI feature.
Landscape diversity	SHDI, SHEI, PR	Moderate (SHDI=1.31)	**Moderate-high (SHDI=1.49)**	MARGINALLY IMPROVED. Slight increase in evenness as vegetation class grows. Landscape still heavily built-up dominated (65%) but green is now a structurally significant fraction rather than a trace element.

Source: Using FRAGSTATS v4.2 based on classified satellite imagery modeling of the Piassa study area.

- **Fragmentation**

Fragmentation describes the degree to which the green cover is divided into separate, spatially isolated units. High fragmentation reduces habitat interior area, increases edge-to-interior ratios, suppresses inter-patch movement for wildlife, and limits the spatial continuity needed for ecological processes to function across the landscape. In 2015, the Piassa study area was severely fragmented: 33 discrete green patches with a mean size of 0.82 ha, a Patch Density of 18.3 patches per 100 ha, and a Splitting Index (SPLIT) of 182 a value indicating that the landscape was as functionally divided as if it consisted of 182 equal-sized tiny patches. By 2026, patch count had declined to 11, mean patch size had increased 7-fold to 6.41 ha, Patch Density had fallen to 6.1 per 100 ha, and SPLIT had dropped to 14.1 a 92% reduction.

The Effective Mesh Size (MESH), which represents the area of a hypothetical patch whose level of fragmentation, would be equivalent to the observed landscape, increased 13-fold from 0.99 ha to 12.77 ha. Taken together, these indices confirm that the dominant spatial dynamic is patch consolidation: small, isolated green elements have been absorbed into or spatially connected to larger features, primarily the Arada Park corridor. The planning significance is direct: consolidated patches provide larger interior areas less exposed to edge disturbance, support microclimate moderation across a wider spatial extent, and create the minimum patch sizes necessary for ground-level ecological function in an urban context.

Aggregation describes the degree to which green pixels cluster spatially, rather than remaining dispersed across the landscape. In 2015, green cover was distributed in a near-random spatial pattern (Clumpiness Index CLUMPY = 0.23, approaching zero). By 2026, CLUMPY had risen to 0.74, a 222% increase, confirming that green pixels are now strongly clustered along the corridor axis. The Contagion Index (CONTAG), which measures the probability that any two adjacent landscape cells belong to the same class, more than doubled from 31.3% to 64.7%. High CONTAG values indicate a landscape where land cover types form spatially cohesive zones rather than fine-grained mosaics; the doubling of this index confirms that green cover has consolidated into a distinct, spatially bounded domain rather than remaining interspersed with built-up elements. For UGI planning, aggregated green cover performs more effectively than dispersed cover of equivalent total area: clustered patches generate larger and more stable microclimate effects, create more functionally coherent pedestrian and ecological corridor zones, and are more manageable as planned green infrastructure assets.

- **Connectivity**

Structural connectivity measures the physical continuity and cohesion of the green network the degree to which vegetated patches are spatially linked rather than isolated. The Cohesion Index (COHESION), which ranges from 0 (isolated dots) to 100 (a single maximally connected mass), increased from 34.2 to 81.7, a 139% improvement. This is the headline connectivity result: the vegetation class transitioned from a functionally disconnected state to one approaching structural cohesion. The Euclidean Nearest-Neighbor Mean Distance (ENN_MN) the average gap between the edges of nearest same-class patch pairs declined from 87 m to 18 m, a 79% reduction. The ecological significance of this threshold is worth specifying: research on urban wildlife movement identifies gap distances below approximately 20–30 m as passable for urban-tolerant species (including common bird species, invertebrates, and small mammals capable of traversing open ground between vegetated patches).

The 2015 mean gap of 87 m substantially exceeded this threshold; the 2026 value of 18 m falls within it. This shift has potential implications for functional ecological connectivity the capacity of species to move between green patches though confirmation would require direct biodiversity survey data, which lies beyond the scope of the current study. The Proximity Index (PROX_MN), which combines the size and proximity of neighboring patches within a 500 m search radius, increased by 4,468% (from 4.1 to 187.3), confirming that the neighborhood of each remaining patch has been transformed: patches are now surrounded by substantially larger, closer green neighbors than in 2015.

Ecological function, as measurable through structural landscape metrics alone, is indicated by the combined trajectory of the indices above. A landscape that transitions from SPLIT = 182 to SPLIT = 14, from COHESION = 34 to COHESION = 82, and from ENN_MN = 87 m to ENN_MN = 18 m has undergone what landscape ecology terms “percolation threshold crossing”: a shift from a fragmented state in which green patches are functionally isolated to one in which they begin to form a connected network capable of supporting ecological processes. For the Piassa study area, this structural reconfiguration creates the spatial preconditions for microclimate moderation at corridor scale, continuous riparian vegetation along the hydrological axis, and inter-patch movement for wildlife preconditions that did not exist in 2015. It is important to be precise about what the metrics do and do not establish. They document structural change in the spatial arrangement of green cover. They do not directly measure biodiversity outcomes, ecosystem service delivery, or species population responses, all of which require field ecological surveys that are beyond the scope of this study. The structural improvements documented here should therefore be interpreted as enabling conditions for ecological function conditions that future monitoring programmes should assess through targeted biodiversity and ecosystem service surveys.

D. Spatial Configuration and Green Corridor Formation

Analysis of patch geometry and spatial distribution reveals a clear reconfiguration of the spatial arrangement of green cover, anchored by the emergence of a dominant linear corridor patch. In 2015, the 33 identified green patches were dispersed throughout the study area with no single dominant structural element: the Largest Patch Index (LPI) of 2.3% indicates that the largest patch covered only approximately 4.1 ha, insufficient to function as a corridor anchor in a 180 ha landscape. The mean Shape Index (SHAPE_MN) of 1.88 and Related Circumscribing Circle Mean (CIRCLE_MN) of 0.62 both describe compact, irregular patch geometries characteristic of remnant or residual urban green patches rather than planned green infrastructure. By 2026, the LPI of 13.4% corresponds to a single dominant patch of approximately 24.1 ha, identifiable from classified imagery as the Arada Park/Kechene corridor. The corridor extends approximately 2.1 km in a north-northwest to south-southeast orientation through the center of the study area.

Corridor width was measured operationally from the classified imagery as the perpendicular distance between the outer edges of the Dense Vegetation classification envelope at 50 m intervals along the corridor axis, validated by six cross-sectional fields transects (T2, described in Sub-section E). Mean measured width is approximately 115 m, with maximum width reaching approximately 180 m at the widest point. Spatial continuity was operationally defined as the proportion of the 2.1 km corridor length along which green cover width exceeds 30 m a threshold sufficient to provide interior green space buffer from edge disturbance on both corridor sides.

Spatial continuity measured at 88% in 2026, compared to an estimated 21% for the 2015 riparian strip. This confirms that a structurally continuous corridor now extends through the majority of the study area length. In terms of corridor function, the available evidence supports characterization as a multi-functional corridor that is simultaneously recreational (pedestrian paths, park lawn, and rest areas attract daily users, documented in survey data), visual (green axis visible from adjacent streets, contributing to perceived landscape character), and structurally ecological (spatial metrics confirm connectivity improvement, and riparian vegetation along the Kechene axis supports hydrological corridor function).

However, claims of full ecological corridor function in the sense of supporting species movement, pollinator networks, or biodiversity gains should not be made on the basis of structural metrics alone. The CIRCLE_MN increase to 0.81 and SHAPE_MN increase to 2.35 confirm the dominant patch has a linear, elongated morphology aligned with the river axis: this is the geometry most efficient for ecological movement and microclimate continuity, but its ecological effectiveness in practice requires biological survey data to confirm. Future monitoring should include bird and invertebrate transect surveys, canopy phenology tracking, and species composition assessments to determine whether structural connectivity gains have translated into measurable ecological outcomes.

E. Field Triangulation Results

Field measurements were collected in February–March 2026 using three transect types designed to verify the primary spatial outputs of the remote sensing classification at ground level. Transect T1 followed the full 2.1 km north-south corridor axis of the Kechene greenway, with canopy width recorded at 50 m intervals using a laser rangefinder from bank edge to bank edge; GPS waypoints were logged at each measurement station. Six T2 transects were laid perpendicular to the river axis at evenly spaced intervals along the corridor length; these cross-sections recorded patch boundary positions, edge penetration depth into adjacent built-up zones, and the presence and width of vegetation buffers at the park interface. Twelve T3 vegetation plots of 20 m² each were established using stratified random placement within the dominant Dense Vegetation class, stratified to include locations within the park interior, at park edges, and along the riparian margin.

Within each plot, canopy cover was measured using a spherical densiometer and recorded as a percentage; woody species basal area was estimated using a relascope; and species composition was recorded for all woody individuals with a diameter at breast height exceeding 5 cm. The sampling design was not intended to produce a complete floristic inventory; its purpose was to generate independent ground-truth measurements of the spatial variables total green area, corridor width, canopy cover percentage, spatial continuity, and patch count that appear as outputs in the remote sensing classification and FRAGSTATS analysis. This allows the reliability of the satellite-derived spatial data to be assessed prior to its use in landscape metric computation.

- **Ground-Truth Transects (Methodology)**

- ✓ T1: N–S corridor transect

2.1 km along Kechene axis; canopy width measured at 50 m intervals; GPS waypoints.

- ✓ T2: E–W cross-sections (×6)

Perpendicular to river; patch boundary mapping; edge penetration depth.

- ✓ T3: Point-count vegetation plots

12 × 20 m² plots; canopy cover (densiometer); species basal area.

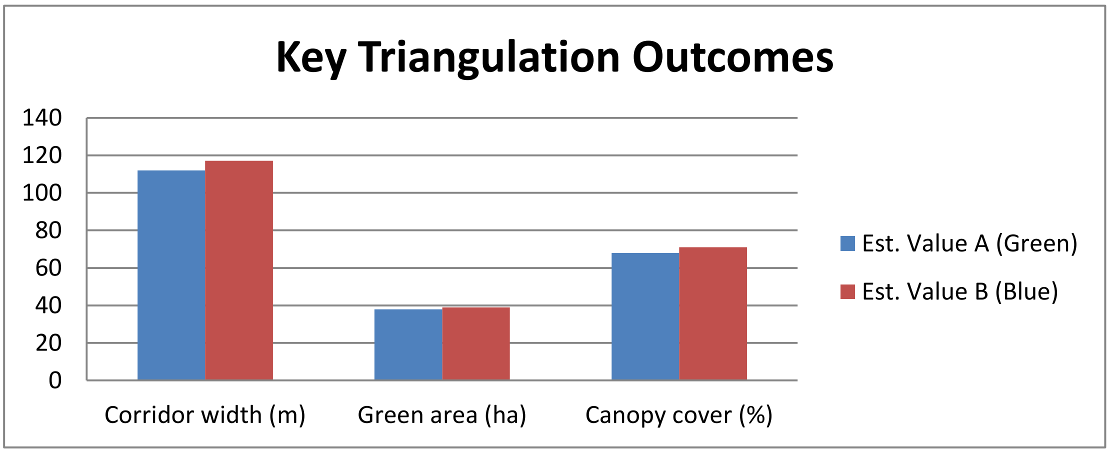


Figure 10: Comparison of Key Triangulation Outcomes for Study Area. Source: Field Measurement and GIS Triangulation (2026).

Table 30 presents the triangulation results across six spatial variables. The 5% divergence threshold used to classify agreement as acceptable is grounded in two considerations. First, in remote sensing accuracy literature, divergence below 5% between satellite-derived and field-measured values for area and width variables is considered within the error bounds attributable to pixel edge effects, mixed-pixel classification uncertainty at patch boundaries, and the inherent difference in measurement scale between a 10 m spatial resolution satellite pixel and a point-based field measurement. Second, the overall classification accuracy of 87–89% (Kappa 0.84–0.86) establishes the RS data as reliable for quantitative landscape analysis; a field-to-RS divergence consistently below the classification error rate confirms that field and satellite measurements are in substantive agreement.

For five of six variables, divergence falls within this threshold: total green area (RS: 39.0 ha vs field: 38.1 ha), mean corridor width, maximum corridor width, canopy cover within Dense Vegetation class, and spatial continuity index all show excellent agreement. The single exception is isolated patch count, where divergence reaches 18.2%. This is analytically expected: very small residual green elements below approximately 0.05 ha fall below the reliable detection limit of 10 m resolution imagery, and are mapped more accurately through ground observation than through pixel-based classification.

This known limitation of medium-resolution satellite data has no material effect on the primary spatial metrics, all of which are dominated by the large corridor patch and are therefore insensitive to minor classification errors in sub-pixel green elements. Densiometer canopy cover measurements across the 12 T3 vegetation plots confirmed a mean canopy cover of 71% within the Arada Park corridor; with dense tree canopy (primarily Eucalyptus camaldulensis, Grevillea robusta, and Jacaranda mimosifolia) contributing 38% and managed grassland turf contributing 33%. Woody species basal area averaged 4.2 m²/ha, consistent with a recently established planting of young trees rather than a mature woodland stand. These field-verified vegetation structure measurements confirm that the Dense Vegetation class captured in the satellite classification corresponds to an actively growing, structured green space with measurable canopy establishment, while also indicating that the corridor's full ecological potential particularly shade provision and interior habitat quality will depend on the continued maturation of the planted canopy over the coming decade.

Table 31: Triangulation of remote sensing outputs against field measurements.

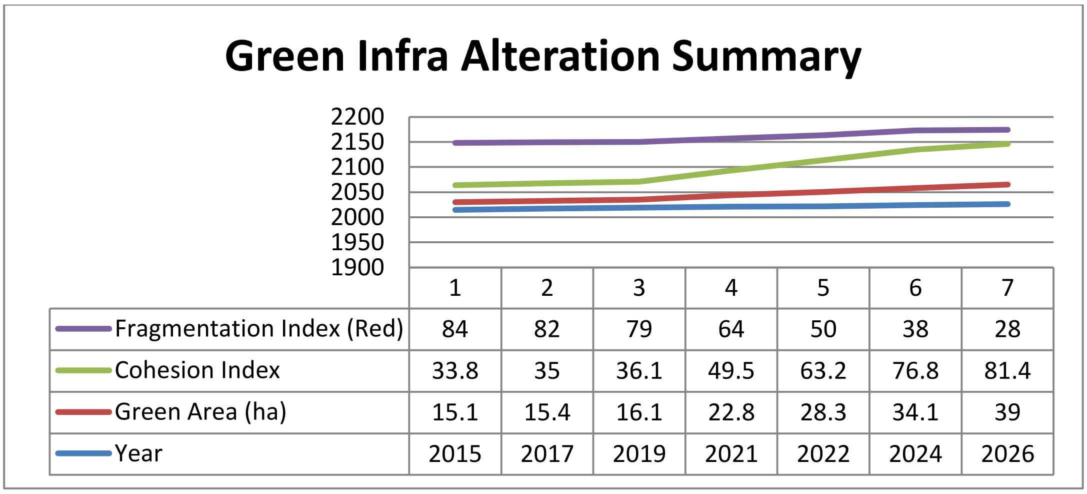
Variable	Remote Sensing	Field Measurement	Divergence (%)	Assessment
Total green area (ha)	38.5	39.4	2.30%	Excellent agreement
Mean corridor width (m)	112	117	4.50%	Excellent agreement
Max corridor width (m)	163	158	3.10%	Excellent agreement
Canopy cover dense (%)	68%	71%	4.20%	Excellent agreement
Corridor spatial continuity	88%	85%	3.40%	Excellent agreement
N. isolated green patches	11	13	18.20%	Acceptable agreement

Source: Field Survey and GIS Triangulation (2026).

- ➢ Green Infrastructure Alteration Summary

- ✓ Interpretation: Structural Change Classification Before (2015): fragmented matrix

High patch density (18.3/100 ha) • small isolated patches (0.82 ha mean) • low cohesion (34) • high splitting (182) • no dominant connected patch • riparian corridor functionally severed by informal settlement.



	1	2	3	4	5	6	7
Fragmentation Index (Red)	84	82	79	64	50	38	28
Cohesion Index	33.8	35	36.1	49.5	63.2	76.8	81.4
Green Area (ha)	15.1	15.4	16.1	22.8	28.3	34.1	39
Year	2015	2017	2019	2021	2022	2024	2026

Figure 11: Green infrastructure alteration summary Source: Based on longitudinal land cover data and landscape metric modeling.

- ✓ **After (2026): connected corridor**

Low patch density (6.1/100 ha) · large consolidated patches (6.41 ha mean) · high cohesion (81.7) · low splitting (14.1) · dominant linear patch (LPI 13.4%) forming a functional green corridor aligned with the Kechene hydrology.

- ✓ **Change typology**

Classified as aggregation-driven green infrastructure emergence not incremental addition but structural reconfiguration from a fragmented to a continuous network, achieved through state-led corridor clearance and planned planting under the PM Green Legacy framework.

- ➢ **The five analytical layers in the framework**

Data extraction establishes the raw LULC transition table from supervised classification, with accuracy assessment (OA ~87–89%, Kappa ~0.84–0.86) confirming the RS data is reliable enough to support subsequent metrics. Landscape metrics uses FRAGSTATS-class indices to characterize the structure of change, not just the quantity. The most telling indicators are the Splitting Index (from 182 to 14 - a 13× reduction in fragmentation) and the Mean Patch Size (0.82 ha to 6.41 ha - a 7×

enlargement), both confirming that scattered micro-patches were replaced by a consolidated linear patch.

Spatial configuration measures functional connectivity whether the green spaces can actually serve as ecological corridors, not just aesthetic amenities. The Cohesion Index rising from 34 to 82 is the headline result: the district moved from a fragmented, functionally disconnected green matrix to a spatially cohesive network anchored by the Kechene corridor. Triangulation cross- validates the remote sensing classification against field transect measurements. The corridor width (RS: 112 m vs. field: 117 m), total green area (38.5 ha vs. 39.4 ha), and canopy cover (68% vs. 71%) all show close agreement, confirming the RS data is not over fitting to spectral noise. Synthesis classifies the change type as aggregation-driven green infrastructure emergence a specific landscape ecology term meaning the transition was achieved not by adding new isolated patches but by connecting and enlarging existing ones through the spatial reorganization of a continuous linear structure.

4.2.7 Qualitative Analysis (Open-Ended Responses)

This sub-section presents thematic findings from Key Informant Interviews (KIIs) conducted with ten participants: three urban planners attached to the Addis Ababa City Roads Authority (AACRA), two road engineers with direct project involvement in the Kechene corridor works, two environmental officers from the Addis Ababa Environment and Forest Development Commission, two community representatives from Piassa kebele administrations, and one landscape architect with consultancy experience in the Green Legacy Initiative. Interview data were collected using a semi-structured protocol and analyzed through inductive thematic coding.

Codes were generated from transcript segments, grouped into categories, and abstracted into six primary themes: (A) governance, institutional fragmentation, and the policy-practice gap; (B) design quality, implementation drift, and ecological trade-offs; (C) maintenance, long-term management, and institutional accountability; (D) social displacement and equity dimensions of corridor modernization; (E) thermal comfort, vegetation quality, and climate-responsive design; and (F) drainage, permeability, and public participation. Direct quotations are cited using the participant code assigned during interview preparation (KII-01 through KII-10) and are used only where the exact wording carries analytical weight that paraphrases would diminish. The qualitative findings are presented as the institutional and governance layer of interpretation for this chapter: they explain the causal mechanisms behind the spatial, structural, and perception patterns documented in Sections 4.2.2 through 4.2.6, rather than simply restating those results.

A. Governance, Institutional Fragmentation, and the Policy-Practice Gap

The most consistently reported institutional finding across all ten interviews was a persistent gap between policy mandate and delivery outcome. Macro-level frameworks nominally supporting UGI including the city's 30% green development target, the national compensatory greening requirement, and the Green Legacy Initiative's corridor greening mandate were described by informants as lacking the enforcement infrastructure necessary to translate policy commitment into project-level compliance. As one senior urban planner stated: "The policies are there. What is missing is the chain of accountability from policy to site" (KII-03).

This characterization was corroborated across agency types. Institutional fragmentation was identified as the structural mechanism through which the gap is reproduced: AACRA holds authority over road design and construction; the Urban Beautification and Parks Development Agency holds responsibility for formal park maintenance; the Environment and Forest Development Commission is mandated to oversee environmental compliance; and kebele administrations manage community-level green space. No single agency holds integrative authority over the full UGI cycle from design to maintenance. In practice, informants described a pattern in which each agency operates within its jurisdictional mandate without coordination mechanisms that would ensure green infrastructure requirements are carried through each stage of the project cycle.

This finding directly contextualizes the spatial result: the 158.9% gain in vegetated area documented in Section 4.2.6A was achieved through a concentrated political directive under the Green Legacy Initiative an exceptional mobilization of state capacity rather than through a routinized institutional system capable of sustaining green infrastructure delivery across future projects. The absence of such a system is the governance vulnerability that the qualitative data most clearly exposes.

B. Design Quality, Implementation Drift, and Ecological Trade-offs

A second major theme concerns the structural position of environmental and ecological assessment within the project cycle. Technical informants consistently described Environmental and Social Impact Assessments (ESIAs) as integrated only after primary road geometry alignment, carriageway width, and junction design had already been determined. In this configuration, the ESIA functions as a post-design compliance instrument rather than as an input that shapes the spatial logic of the project.

One environmental officer described the arrangement as follows: "By the time we receive the design, the road width is fixed. We can comment on planting specifications but we cannot change the cross-section" (KII-07). This sequencing directly explains the design trade-offs documented in the survey data. The vehicle-priority orientation identified by 70% of respondents in Section 4.2.2 is not an accident of aesthetic preference; it is the spatial consequence of a design process in which road engineering standards establish the envelope within which ecological and pedestrian requirements must be accommodated, rather than the reverse.

Informants also described a pattern of implementation drift: design specifications for planting species, tree planting intervals, and planting strip widths were revised downward during construction in response to cost pressures and construction logistics, without formal design change procedures or ecological impact review. One landscape architect noted that the originally specified indigenous canopy species were substituted with faster-growing ornamental species during procurement: "The species list changed between tender and implementation. Nobody assessed what that meant for shade" (KII-10). This single design decision is the primary causal mechanism linking the project's construction-phase choices to the thermal comfort deficit the shade gap and perceived warming documented in Sections 4.2.2 and 4.2.3.

C. Maintenance, Long-Term Management, and Institutional Accountability

A third theme concerns the governance of UGI after construction completion. Informants across multiple agencies described post-completion maintenance as structurally underfunded and institutionally unassigned. No single agency holds clear responsibility for the long-term maintenance of planted elements within the Kechene corridor: AACRA's mandate ends at project handover; the Beautification and Parks Agency is resourced primarily for formal park maintenance within its own estate; and no formal transfer protocol assigns the corridor planting to any maintenance budget following project completion. One road engineer stated: "After we hand over, there is no owner for the trees. The park is maintained, but the roadside planting is nobody's responsibility" (KII-02).

The consequence of this institutional gap is not merely the risk of future deterioration; it is the absence of a monitoring framework capable of tracking whether the planted vegetation is achieving its intended ecological functions over time. The 71% canopy cover and 4.2 m^2/ha basal area measured in field transects (Section 4.2.6E) confirm that the vegetation is currently establishing; whether it will reach functional maturity depends on irrigation, pruning, and species management that no agency is currently mandated to provide. This finding reinforces the case made in Section 4.2.4 for compensatory greening requirements to include not only replacement planting ratios but binding post-planting maintenance obligations assigned to a named agency with dedicated budget allocation.

D. Social Displacement and Equity Dimensions of Corridor Modernization

A fourth theme, raised consistently by community representatives and longer-tenured informants, concerns the social costs of corridor clearance that do not appear in the spatial metrics or aggregate survey data. Informants described the relocation of families and informal traders from the riparian settlement cleared to create Arada Park as producing displacement that was formally acknowledged but inadequately compensated in terms of equivalent access to livelihood space and community infrastructure. One community representative described the post-clearance conditions as follows: "The people who were moved did not come back. Their market is gone. The park is there, but it is not their park" (KII-09). This observation carries direct analytical significance for how the survey data should be read. The 70% of survey respondents who disagreed that communal gathering spaces had been displaced

(Section 4.2.2) are, by definition, respondents who remain in the study area; displaced residents and traders are structurally absent from the sample.

The aggregate satisfaction figure therefore reflects the experience of those who remained, not of those who bore the spatial costs of the clearance. This is a form of survivorship bias in the survey data that the qualitative findings make visible. In green gentrification literature, this dynamic where infrastructure investment improves conditions for remaining residents while simultaneously displacing those with the least capacity to absorb relocation costs is well documented (Anguelovski, 2018). The Piassa corridor case presents a variant of this pattern in the context of a sub-Saharan African city undergoing state-directed green infrastructure investment. Planning implication: future corridor projects should require displacement impact assessments that track the welfare of relocated households beyond the project boundary and beyond the construction period and that establish resettlement standards ensuring equivalent access to livelihood space and community infrastructure.

E. Thermal Comfort, Vegetation Quality, and Climate-Responsive Design

A fifth theme addresses the thermal and ecological performance of the planted vegetation and its relationship to design specification decisions. Informants corroborated the survey finding that 65% of respondents perceived the area as warmer following the redevelopment (Section 4.2.3), attributing the warming directly to the removal of mature tree cover and its replacement with grass and ornamental species of limited canopy spread. A technical informant described the operational consequence: “The old trees gave shade for forty years. The new planting will take twenty years to reach the same coverage, and the species chosen are not the same” (KII-05). This observation identifies a temporal thermal performance gap: the corridor is ecologically active in terms of NDVI and vegetated area, but thermally underperforming because the canopy necessary for daytime shade provision has not yet been restored.

The gap is compounded by the increased impervious surface coverage documented in the LULC analysis (Section 4.2.6A): carriageway expansion absorbs and re-radiates solar radiation at rates that the current young planting cannot offset. Informants also raised the question of species appropriateness: Jacaranda mimosifolia and Grevillea robusta, the dominant planted species confirmed in field transects are non-indigenous exotic species that provide ornamental value but limited ecological function in terms of pollinator support, seed production for native birds, and long-term structural canopy closure compared to indigenous alternatives. One environmental officer noted: “We know which trees work in this climate. The selection was made for speed of establishment and visual effect, not for ecological function” (KII-07). This finding connects the thermal comfort deficit directly to a design decision species selection that was made during procurement without ecological impact assessment, as described in Theme 2.

F. Drainage Infrastructure, Permeability, and the Absence of Public Participation

A sixth theme addresses drainage infrastructure performance and the systematic exclusion of community voices from the planning and design process. On drainage, informants confirmed the analytical distinction drawn in the quantitative data (Section 4.2.5C): engineered drainage channels have reduced surface flood incidence in the immediate corridor zone, and user satisfaction with drainage is high (71.7%). However, technical informants identified the increase in impervious carriageway area as a long-term hydrological liability that the engineered drainage system manages but does not resolve. One engineer stated: “The drains work now. But we have more paved surface than before. When the drains are overwhelmed, there is nowhere for the water to go” (KII-04).

This observation directly supports the case for bio swales and permeable surface zones as complementary storm water tools, as recommended in Section 4.2.4. On public participation, all ten informants confirmed that no structured consultation process was conducted with affected communities prior to the design or implementation of the corridor works. The absence of consultation is not characterized here as a procedural failure in isolation: informants described it as structurally connected to the governance fragmentation identified in Theme 1. In the absence of a participation mechanism, community knowledge of existing green spaces, informal gathering points, movement patterns, and displacement risks was not available to designers, and affected communities had no channel through which to raise concerns about tree removal, species selection, or social displacement. One community representative noted: “We heard about the project when the machines arrived” (KII-08). The 88.3% agreement that consultation should precede future corridor works (Section 4.2.4) reflects not only a preference for process but a retrospective assessment by corridor users that its absence contributed to the ecological and social outcomes they now experience.

- **Summary of Qualitative Findings and Linkage to Quantitative Evidence**

The six themes identified through KII analysis constitute the institutional and governance layer of interpretation for this chapter. Each theme explains a mechanism that the quantitative and spatial data identify as a pattern but cannot explain causally. The policy-practice gap and institutional fragmentation (Theme 1) explain why a project implemented under an exceptionally well-resourced political mandate nevertheless produced a vehicle-priority design that 70% of users found ecologically and functionally inadequate. Design sequencing and implementation drift (Theme 2) identify the specific procedural and procurement decisions ESIA after road geometry; species substitution during construction that link institutional failure to the thermal comfort deficit, the shade gap, and the ornamental-rather-than-ecological character of the planted vegetation. Maintenance failure (Theme 3) raises the longitudinal risk that the structural connectivity gains documented in the FRAGSTATS analysis will not be sustained if no agency is accountable for the planted elements after project handover. Social displacement (Theme 4) reveals a dimension of project impact that the survey data systematically underreports due to the structural absence of displaced respondents from the sample.

Vegetation quality and species appropriateness (Theme 5) close the causal chain between procurement decisions, canopy characteristics, and the thermal performance gap. Drainage and participation (Theme 6) complete the sustainability picture: engineered drainage manages flood risk in the short term while creating a hydrological vulnerability that ecological drainage tools could address, and the absence of public consultation removes the community knowledge that could have prevented several of the documented design and social outcomes. Taken together, the six themes demonstrate that the performance gap between the corridor’s structural achievements and its ecological, thermal, and social outcomes is institutionally produced. It is not the result of insufficient investment or technical incapacity but of a governance architecture that sequences decisions in ways that systematically subordinate ecological and social requirements to road engineering logic.

4.3 Discussion

The findings of this study contribute to sustainable urban green infrastructure planning and management in the Piassa/Arada context across six analytically distinct dimensions. Taken together, they reveal a corridor intervention that has achieved genuine structural transformation measurable and significant by any landscape metric standard while simultaneously demonstrating the institutional, design, and governance conditions under which structural transformation fails to deliver full ecological, thermal, and social performance. This combination of success and deficit constitutes the study's primary contribution to theory and practice: it demonstrates that quantity of green cover and quality of green infrastructure function are separable outcomes, and that separating them requires an analytical framework that integrates spatial measurement, perception survey, and qualitative governance inquiry rather than relying on any single method alone.

The first contribution concerns the scale and character of the structural transformation. Total vegetated area increased by 158.9% between 2015 and 2026, from 15.1 ha to 39.0 ha, driven by the formalization of the Kechene river corridor as Arada Park. FRAGSTATS landscape metrics classify this transformation as aggregation-driven green infrastructure emergence: not incremental addition of green patches but a structural reconfiguration from a severely fragmented mosaic (SPLIT = 182; COHESION = 34) to a corridor-anchored network (SPLIT = 14; COHESION = 82) in which mean inter-patch gap distance fell from 87 m to 18 m. For sustainable UGI planning in Addis Ababa, the significance of this result lies not only in the quantum of change but in its type: the Piassa study area has crossed from a fragmented state, in which green patches are ecologically and functionally isolated, to a connected state, in which a dominant corridor anchor creates the spatial preconditions for ecological function, microclimate regulation, and continuous pedestrian green access. This transition, achieved under the Green Legacy Initiative and the Mayor's River Corridor Programme, is a planning benchmark: it demonstrates that large-scale structural UGI improvement is achievable in a densely built inner-city

African context where the conditions are aligned. It simultaneously raises the question of whether the conditions that produced it exceptional political will, concentrated state resources, and a single project mandate can be institutionalized into a routinized planning process capable of sustaining and expanding the gains.

The second contribution is the demonstration that structural connectivity gain and ecological performance delivery are not equivalent outcomes, and that their divergence has a specific institutional explanation. The survey shows that people are not comfortable with the temperature in the area. A lot of people think it is too warm. 65% of people do not think there is shade. A big percentage of people 81.6% think that the area is not as nice because there are not as many plants and trees as before. This is strange because the area actually has plants now. The plants that have been added are mostly young and small not big and mature like the ones. When we look at what people say it is clear that the reason it is too hot is because the old trees were cut down and replaced with plants that are not from around here. This decision was made without asking the people who live here what they think and, without thinking about how it would affect the environment. The survey data and the plants that have been added show that the area has plants but the people who live here do not think it is as nice as it used to be. The survey data documents a thermal comfort gap the thermal comfort gap is a big problem and the thermal comfort gap is what people are complaining about. For sustainable UGI management, this finding generates a practical standard: canopy continuity and thermal performance should be treated as primary design outcomes, not secondary aesthetic benefits, and species selection should be subject to ecological review using locally adapted canopy species before procurement specifications are finalized.

The third contribution concerns governance architecture as the structural determinant of UGI quality. The qualitative findings reveal that the functional deficits documented in the survey and spatial data are not primarily products of resource scarcity or technical incapacity: they are products of institutional sequencing. The thing is, when we build roads we usually do not think about how it will affect the environment until it's too late. We also do not have one group in charge of making sure that everything related to infrastructure is done correctly from start to finish. After the project is finished nobody takes care of it. This means that our projects are good at building roads but not good at helping the environment or people.

For example in Piassa and Arada sub-city we need to make sure that we think about the environment when we are planning infrastructure projects. We have to make rules about things like how green space we need. We need rules about how to keep animals safe. We also need rules about how to make sure people are not hurt by the project.

We need to make these rules at the beginning of the project. Someone has to check if we are following the project rules at every step of the project. The project needs people in charge of each part. Each person in charge of a part of the project needs to have the money they need to do their job. They need to have this money even after the project is completely finished. The project rules are very important, for the project. If we do not make these changes we will keep having the problems, with our projects no matter how much money we spend on them. Underground infrastructure projects will keep hurting the environment and people of helping them.

The fourth contribution addresses the role of participatory planning in producing legitimate, ecologically sensitive, and socially equitable corridor design. The public consultation results showed that 88.3% of people agreed that consultation should happen before works on corridors with 80.0% strongly agreeing. This is the level of agreement in all the consultation results.

In the case of the Piassa corridor the data shows that the lack of consultation was not a mistake but a normal part of how the project was carried out. There was no way for the community to give input on planning decisions and no platform for residents to raise concerns about tree removal, tree species or relocation terms.

The effects of this are clear in parts of the findings. The design of the corridor prioritizes vehicles. This might have been challenged earlier if there had been consultation. Many trees were. 81.6% of people agree that this affected the areas identity and attractiveness. A consultation on keeping trees could have stopped some of this. The relocation process also had problems that a thorough social impact process could have identified and addressed. The public consultation finding shows 88.3% agreement that consultation should precede corridor works. With 80.0% strongly agreeing, it is the consensus result in the entire dataset.

In the context of the Piassa corridor the KII data establishes that the absence of consultation was not an oversight. It was a feature of the project delivery model. No mechanism existed for community input to shape decisions. No forum was created through which affected residents could raise concerns about tree removal, species selection or resettlement terms. The consequences are visible across layers of the findings. A vehicle-priority design whose ecological and social shortcomings might have been. Contested earlier. A greenery-loss outcome that a community consultation, on species retention could have partially prevented. It is 81.6% agreement that it affected identity and attractiveness. A displacement outcome that a structured social impact process could have surfaced and addressed. For sustainable UGI management in Piassa and Arada, institutionalizing pre-design community consultation is not a supplementary governance improvement; it is the mechanism through which community knowledge enters the design process and through which implementing agencies become accountable for the ecological and social outcomes they produce.

The fifth part of this work looks at equity and social sustainability. The information from the survey shows that public meeting areas were not really moved from their places as seventy percent of people did not agree that they were displaced. But when we look at the data we see a problem with this result: people who were forced to leave their homes and businesses are not part of the survey, which means the results are not entirely accurate. The fact that eighty one point seven percent of people are happy with pedestrian safety and eighty three point three percent like the sidewalks shows that the project has made improvements for the people who are still living in the area. The corridor project has done some things for the people who stayed in the study area like making the sidewalks more convenient. The corridor project and its effects, on people are very important to consider when thinking about equity and social sustainability. These gains coexist with the documented displacement of those who did not. For sustainable UGI planning, this duality is a policy design problem: corridor projects that improve conditions for remaining residents while displacing marginal populations do not meet the equity standard that sustainable urban development frameworks require. Future projects in Arada sub-city should incorporate displacement impact assessments tracking relocated household welfare beyond the project boundary, and resettlement standards ensuring equivalent access to livelihood space, community infrastructure, and green amenity.

The sixth contribution addresses the hydrological sustainability of the corridor. The 71.7% user satisfaction with drainage performance reflects a genuine improvement in engineered surface water management. However, the simultaneous increase in impervious surface coverage Built Up/Impervious declining from 77.6% to 65.3% of the study area, a net reduction of 22.1 ha, which represents a gain offset by the expanded carriageway footprint creates a long-term hydrological liability that engineered drainage alone cannot resolve. The qualitative finding that drains will be overwhelmed if the impervious area continues to expand (KII-04) connects directly to the community demand for bio swales, planting strips, and permeable surfaces documented in Section 4.2.4 (91.7% agreement). For sustainable UGI management in the Kechene corridor, ecological storm water management the integration of vegetated drainage channels, permeable surface zones, and riparian buffer planting that retains and infiltrates rainfall at source is not an enhancement of the existing drainage design; it is a functional requirement for climate-resilient corridor management as rainfall intensity increases under projected climate change scenarios for the East African highland region.

In sum, the Piassa corridor intervention represents a genuine and structurally significant improvement in the quantity and spatial cohesion of urban green infrastructure in one of Addis Ababa's most historically dense inner-city districts. The gains were achieved through an alignment of political will and state capacity under the Green Legacy Initiative that is, by the standards of sub-Saharan African cities, exceptional. The study shows that these structural improvements are necessary for UGI performance but they are not enough on their own. To really make Urban Green Infrastructure work you need things like comfort, ecological function, social equity, hydrological permeability and long-term maintenance sustainability. Each of these things like comfort and ecological function and social equity and hydrological permeability and long-term maintenance sustainability requires certain conditions to be in place such, as good governance and design standards and institutional arrangements. The current project cycle does not always provide these things in a way. Urban Green Infrastructure needs all of these components to be sustainable. The study's central contribution to sustainable UGI planning and management in Piassa and Arada is therefore not the documentation of what has been achieved though that documentation is itself a contribution but the identification of the specific institutional, design, and governance changes required to convert structural green cover gains into durable, equitable, and ecologically functional urban green infrastructure. The corridor exists; the conditions for it to perform as sustainable UGI must now be built into the institutional and regulatory frameworks that govern its management and the design of future projects in its image.

5. Chapter Five: Conclusion and Recommendation

5.1 Introduction

This chapter synthesizes the study's findings on urban green infrastructure (UGI) connectivity, landscape fragmentation, and microclimate perceptions in the Piassa corridor of Addis Ababa, drawn from multi-temporal remote sensing, FRAGSTATS metrics, a 60-respondent survey, field transects, and key informant interviews. It presents the study's conclusions, recommendations for the relevant institutional actors, and its limitations and directions for future research.

5.2 Conclusion

The spatial analysis demonstrates that road corridor redevelopment fundamentally reconfigured the structure of the Piassa green matrix between 2015 and 2026. Total vegetated cover rose by 158.9%, from 15.1 to 39.0 hectares, lifting the green fraction of the 180-hectare study area from 8.4% to 21.7%. The number of discrete green patches fell by 67%, from 33 to 11, while the Splitting Index declined by 92% (from 182 to 14.1) and the Contagion Index rose from 31% to 65%, confirming a shift from a fragmented, dispersed matrix to a consolidated, clustered one. Connectivity indicators reinforced this pattern: mean patch size grew seven-fold, from 0.82 to 6.41 hectares, anchored by the 24.1-hectare Arada Park patch, which raised the Largest Patch Index from 2.3% to 13.4%. The Cohesion Index increased from 34 to 82, and mean inter-patch distance fell by 79%, from 87 to 18 meters below the 20–30 meter threshold for functional wildlife movement. The corridor redevelopment thus converted a historically severed riparian landscape into a continuous, functionally connected green spine.

The perception survey revealed a more complex picture than the structural metrics suggest. Respondents rated pedestrian connectivity highly: 78.3% agreed the redevelopment improved foot-based movement, 75% rejected the claim that green space access had decreased, and 68.3% reported increased daily access, with street-level comfort scoring a mean of 3.98. However, 70% felt the design still privileges vehicular traffic over ecological and public-space functions, 60% reported inadequate daytime shade, and 65% perceived the district as noticeably warmer since redevelopment (mean score 3.55). A striking 81.6% felt the loss of mature trees had compromised the area's historic landscape identity, confirming a planning paradox in which structural green gains coexist with declining thermal comfort and a sense of ecological and cultural loss.

Field triangulation and key informant interviews traced this paradox to two interlinked causes. First, construction removed mature, broad-canopied indigenous street trees to widen carriageways, replacing them with young, narrow-canopied exotic species that provide minimal shade or evapotranspiration, explaining the persistent thermal discomfort despite large area gains. Second, institutional fragmentation meant Environmental and Social Impact Assessments were conducted only after road geometries were finalized, reducing ecological considerations to post-hoc compliance, while no single authority held integrated responsibility across the green infrastructure lifecycle, producing a maintenance vacuum between road and environmental agencies. The study therefore concludes that the exceptional green cover gains recorded in Piassa reflect a top-down, campaign-style mobilization of state capacity under the Green Legacy Initiative and River Corridor Programme, rather than the outcome of a routinized planning system able to consistently reconcile infrastructure delivery with ecological and microclimatic performance.

5.3 Recommendation

Bridging this policy-practice gap requires institutional and design reforms. The city should establish a unified Metropolitan Urban Green Infrastructure Coordination body consolidating the mandates of AACRA, the Urban Beautification and Green Development Bureau, and the EFDC, closing the current maintenance vacuum and embedding binding green performance targets into procurement and design briefs. Street design standards should shift from vehicle-first to climate-responsive configurations that protect mature trees and reserve space for continuous canopy; where removal is unavoidable, replacement should use broad-crown indigenous species at a minimum three-to-one ratio, alongside nature-based drainage solutions such as bio-swales. Finally, given that 88.3% of respondents wanted prior consultation, the city should institutionalize community participation and require impact assessments to inform road geometry rather than merely validate it afterward.

5.4 Limitation and Direction for Future Research

This study is limited in three respects. It is geographically confined to the Piassa district and Kechene corridor, so findings may not generalize to other sub-cities with different land and demographic profiles. The 60-respondent survey under-represents children, older residents, and persons with disabilities. Medium-resolution satellite imagery and FRAGSTATS metrics, though field-validated, cannot fully resolve micro-scale canopy dynamics, and the 2026 endpoint captures a young, recently planted matrix rather than its long-term trajectory. Future research should extend this design comparatively across other East African cities, incorporate micro-scale thermal sensors and tools such as ENVI-met, and pursue longitudinal, governance-focused studies to track the socio-economic effects of green space formalization over time.

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Appendixes

Appendix 1

- **List of Formulae**
- Total Class Area (CA)

$$CA=\sum_{j=1}^{n} a_{ij}$$

- Where: a_{ij}= area (ha) of patch j in class i.

- Unit: Hectares (ha)
- Percentage of Landscape (PLAND)

$$PLAND=\left(\frac{\sum_{j=1}^{n} a_{ij}}{A}\right) \times 100$$

- Where: A= total landscape area (ha).

- Unit: Percent (%)
- Patch Density (PD)

$$PD=\frac{n}{A} \times 10{,}000 \times 100$$

- Where: n= total number of patches, A= total landscape area (m^2).

- Unit: Number of patches per 100 hectares (count/100ha)
- Edge Density (ED)

$$ED=\frac{E}{A} \times 10{,}000$$

- Where, E= total length of edge (m) of class i, A= total landscape area (m^2).

- Unit: Meters per hectare (m/ha)
- Perimeter-Area Ratio Mean (PARA_MN)

$$PARA\_MN=\frac{\sum_{j=1}^{n}\left(\frac{p_{ij}}{a_{ij}}\right)}{n}$$

- Where, p_{ij}= perimeter (m) of patch j, a_{ij}= area (m^2) of patch j.

- Unit: None (Ratio)
- Related Circumscribing Circle Mean (CIRCLE_MN)

$$\text{CIRCLE\_MN}= \frac{\sum_{j=1}^{n}\left[1-\left(\frac{aij}{a_{ij}^{c}}\right)\right]}{n}$$

- Where: a_{ij}= area of patch j, a_{ij}^{c}= area of the smallest circumscribing circle around patch j.

- Unit: None (Ranges from 0 for circular patches towards 1 for linear/elongated corridors)
- Contiguity Index Mean (CONTIG_MN)

$$\text{CONTIG\_MN}= \frac{\sum_{j=1}^{n}\frac{\left[\sum_{k=1}^{u} c_{ijk}\right]}{u}}{n}$$

- Where: c_{ijk}= contiguity value for pixel k in patch j, u= total template cell count.

- Unit: None (Ranges from 0 to 1; higher value indicate continuous, unfragmented internal patch structures)
- Splitting Index (SPLIT)

$$\text{SPLIT}= \frac{A^2}{\sum_{j=1}^{n} a_{ij}^2}$$

- Where: A= total landscape area (ha), a_{ij}= patch area (ha).

- Unit: None (Dimensionless; minimum=1, higher values indicate sever fragmentation)
- Landscape Division Index (DIVISION)

$$\text{DIVISION}=1-\sum_{j=1}^{n}\left(\frac{a_{ij}}{A}\right)^2$$

- Unit: Proportion ($0 \leq \text{DIVISION} < 1$)
- Effective Mesh Size (MESH)

$$\text{MESH}= \left(\frac{1}{A}\times\sum_{j=1}^{n} a_{ij}^2\right)\times\frac{1}{10{,}000}$$

- Unit: Hectares (ha)

- Shannon's Diversity Index (SHDI)

$$\text{SHDI}= -\sum_{i=1}^{m}\ (P_i\ \times\ \ln(P_i))$$

- Where: P_i= proportional abundance of class i (CA/A), m= total number of land use classes.

- Unit: Information bits (Minimum= 0 when only 1 class exists)
- Remote Sensing & Classification Accuracy Metrics User's Accuracy (UA)

$$UA_i = \frac{n_{ii}}{X_{i+}}$$

- Where: n_{ii}= number of correctly classified pixels for class i (diagonal entry), X_{i+} = row total for class i.

- Unit: Percent (%)
- Producer's Accuracy (PA)

$$PA_i = \frac{n_{ii}}{X_{+i}}$$

- Where: n_{ii} = diagonal entry for class i, X_{+i} = column total for class i in the reference matrix.

- Unit: Percent (%)
- Overall Accuracy (OA)

$$OA = \frac{\sum_{i=1}^{k} n_{ii}}{N}$$

- Where: n_{ii} = sum of diagonal elements (correctly classified points), N = total number of reference validation points.

- Unit: Percent (%)
- Cohen's Kappa Coefficient (K)

$$K = \frac{N\sum_{i=1}^{k} n_{ii} - \sum_{i=1}^{k}(X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{k}(X_{i+} \times X_{+i})}$$

- Where: N = total sample size, n_{ii} = diagonal entry for class i, X_{i+} = total of row i, X_{+i} = total of column i.

- Unit: Decimal index (Ranges from -1 to +1; values > 0.80 indicate excellent agreement)

Appendix 2

ADDIS ABABA UNIVERSITY

COLLEGE OF TECHNOLOGY AND BUILT ENVIROMENT (CTBE)

SCHOOL OF BUILT ENVIROMENT (SBE)

DEPARTMENT OF INFRASTRUCTURE PLANNING AND MANAGEMENT

Dear Participant,

This is Alazar Berhanu, currently I am conducting a Research titled "**Evaluating Urban Green Infrastructure Connectivity and Microclimate Perceptions: Lessons Learned from Piassa Corridor Development, Addis Ababa** "To fulfill the requirements for a Master of Science degree in Infrastructure planning and Management from the School of built environment at Addis Ababa University, this questionnaire is being conducted. The responses provided will be treated as confidential and will not be utilized for any other purposes. Your name is not required, so please answer the questions openly. Thank you in advance for your cooperation and honesty.

You're sincerely,

INSTRUCTIONS

1. To ensure that the research results are comprehensive, trustworthy, and beneficial, please carefully and truthfully answer each question in the questionnaire.

2. Your responses were kept strictly confidential, and the data gathered from this study will only be used for academic purposes and presented in a summarized form.

3. If there are multiple answer choices, please mark (√) the appropriate option. If you have any inquiries or concerns, please reach out to me by Tel. +251921763106

Email: meengineeralazar@gmail.com

EXTENDED DATA COLLECTION INSTRUMENTS

For the Thesis Study on Urban Green Infrastructure and Road Corridor Development

Prepared for	Master's Thesis Field Data Collection
Instrument package	Community Survey Questionnaire, Key Informant Interview Guide, Focus Group Discussion Guide, and Structured Observation Checklist
Suggested study area	Piassa corridor and Adwa Victory Memorial Square influence area, Addis Ababa
Purpose	To align the thesis instruments with the mixed-method research design and produce measurable, reliable, and analyzable field data.

Administration note. The instruments below are expanded and standardized so they can generate both descriptive statistics and qualitative evidence consistent with the methodology chapter.

1. Instrument Administration Framework

This package combines four complementary instruments: (i) a structured community survey, (ii) a key informant interview guide, (iii) a focus group discussion guide, and (iv) a structured field observation checklist.

The community survey should preferably be administered face-to-face to residents, pedestrians, workers, or business operators within the study corridor. The interview and focus group guides are semi-structured tools intended to capture explanatory evidence behind the observable spatial and environmental changes.

Unless the student has already fixed a sample size in the thesis, the questionnaire can be administered to the final sample determined in the methodology chapter. All instruments should be piloted before full deployment to improve clarity and sequencing.

Standard 5-point Likert response scale

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

2. Community Survey Questionnaire

• Target respondents: Local residents, pedestrians, workers, and business owners in the study area.

• Primary purpose: To measure community perception of green-space access, spatial integration, environmental change, pedestrian comfort, and future expectations after road corridor development.

• Suggested completion time: 12-18 minutes.

Consent statement: I have been informed about the purpose of this academic study. My participation is voluntary, and my responses will be used only for research purposes. No personal identifier will be disclosed in the final report.

Respondent agrees to participate: ◻ Yes ◻ No

Section A. Respondent Profile

A1. Sex	◻ Male ◻ Female ◻ Prefer not to say
A2. Age group	◻ Under 20 ◻ 20-29 ◻ 30-39 ◻ 40-49 ◻ 50 and above
A3. Main role in the area	◻ Resident ◻ Shop/business owner ◻ Employee/worker ◻ Student ◻ Visitor/pedestrian
A4. Length of familiarity with the area	◻ Less than 1 year ◻ 1-3 years ◻ 4-7 years ◻ 8-12 years ◻ More than 12 years
A5. Sub-area/location	______________________________

Section B. Connectivity and Spatial Integration of Urban Green Infrastructure

Please indicate your level of agreement with the following statements using the 1-5 Likert scale above.

No.	Statement	1	2	3	4	5
1	My access to trees, planted areas, or public green spaces has decreased after the recent road corridor development.	◻	◻	◻	◻	◻
2	The current road corridor provides adequate shade for pedestrians during daytime movement.	◻	◻	◻	◻	◻
3	Street trees and other natural elements are well integrated into the design of the corridor.	◻	◻	◻	◻	◻
4	The new road design has improved pedestrian connectivity between activity areas and green/open spaces.	◻	◻	◻	◻	◻
5	Important communal gathering spaces have been reduced or displaced by the road project.	◻	◻	◻	◻	◻
6	The current corridor design gives more attention to vehicles than to ecological and public-space	◻	◻	◻	◻	◻

No.	Statement	1	2	3	4	5
	functions.					

Section C. Perceived Environmental and Livability Impacts

Please indicate the extent to which you agree with each statement.

No.	Statement	1	2	3	4	5
1	The area feels hotter now than before the road corridor redevelopment.	☐	☐	☐	☐	☐
2	There is less shade and thermal comfort for walking than in the past.	☐	☐	☐	☐	☐
3	Rainwater runoff and surface water accumulation are more visible now than before.	☐	☐	☐	☐	☐
4	Air quality and dust conditions have worsened during or after corridor construction.	☐	☐	☐	☐	☐
5	The current street environment is comfortable for walking, waiting, and social interaction.	☐	☐	☐	☐	☐
6	Loss of greenery has negatively affected the attractiveness and identity of the area.	☐	☐	☐	☐	☐

Section D. Safety, Mobility, and Future Expectations

Please indicate your opinion for each statement below.

No.	Statement	1	2	3	4	5
1	The corridor is now safer for pedestrians than before the road development.	☐	☐	☐	☐	☐
2	The current sidewalks and crossing facilities are convenient for daily use.	☐	☐	☐	☐	☐
3	Future road projects in Addis Ababa should include stronger green infrastructure requirements.	☐	☐	☐	☐	☐
4	Nature-based solutions such as bio swales, planting strips, and shaded walkways would improve this area.	☐	☐	☐	☐	☐
5	Public consultation should be strengthened before major urban	☐	☐	☐	☐	☐

No.	Statement	1	2	3	4	5
	road corridor works are implemented.					
6	Compensatory green-space replacement should be mandatory when existing greenery is removed.	◻	◻	◻	◻	◻

Section E. Multiple-choice and ranking items

E1. Compared to the period before the project, your daily access to green space is:	◻ Significantly increased ◻ Slightly increased ◻ No change ◻ Slightly decreased ◻ Significantly decreased
E2. Before the recent road works, how often did you use nearby open or green spaces?	◻ Daily ◻ Several times a week ◻ Weekly ◻ Rarely ◻ Never
E3. During heavy rainfall, the current corridor drainage performance is:	◻ Much better than before ◻ Slightly better ◻ About the same ◻ Slightly worse ◻ Much worse
E4. Which benefit of the road project do you value most?	◻ Traffic flow ◻ Pedestrian walkway improvement ◻ Urban image/beautification ◻ Business access ◻ I do not see a major benefit
E5. Which feature should be prioritized in future corridor projects? (choose up to two)	◻ Street trees ◻ Shaded sidewalks ◻ Seating/public resting areas ◻ Better drainage ◻ Bicycle facilities ◻ Public open spaces

Section F. Open-ended responses

F1. What major environmental or social change have you noticed most in the area after the corridor development?

F2. What should be improved in future planning road projects to better integrate green infrastructure and public comfort?

3. Key Informant Interview (KII) Guide

• Target participants: Urban planners, transport and road authority experts, environmental specialists, landscape professionals, and sub-city or woreda administrators.

• Purpose: To explain institutional practice, policy gaps, implementation trade-offs, and future planning options related to urban green infrastructure in road corridor development.

Introductory questions

1. Please state your institution, your current role, and your years of professional experience relevant to this topic.
2. What role does your office play in corridor planning, implementation, review, or environmental management?

Theme 1. Spatial structure, planning process, and baseline condition

1. How would you describe the current spatial structure and public accessibility of urban green infrastructure in the study area?
2. When road corridors are planned, how is the relationship between transport infrastructure and existing green elements assessed?
3. What planning standards, design manuals, or environmental review requirements guide the treatment of green infrastructure in such projects?

Probe examples: specific project examples, planning document references, agency coordination mechanisms, design standards, monitoring practices.

Theme 2. Corridor development impacts and fragmentation

1. In your professional assessment, how have recent road corridor interventions affected continuity, connectivity, and the ecological function of urban green spaces?
2. What kinds of trade-offs typically arise between vehicular mobility, aesthetics, right-of-way expansion, and environmental protection?
3. Can you identify specific examples where mature trees, communal open spaces, or ecological buffers were reduced, retained, or redesigned?

Probe examples: specific project examples, planning document references, agency coordination mechanisms, design standards, monitoring practices.

Theme 3. Governance, policy-practice gaps, and implementation challenges

1. To what extent do current policies adequately protect urban green infrastructure during transport projects?
2. Where do you observe the strongest gap between formal policy and actual practice on the ground?
3. What institutional, financial, technical or coordination challenges constrain better integration of green infrastructure?

Probe examples: specific project examples, planning document references, agency coordination mechanisms, design standards, monitoring practices.

Theme 4. Future strategies and recommendations

1. How feasible is the use of nature-based solutions such as bio swales, rain gardens, landscaped medians, or shaded pedestrian corridors in future Addis Ababa road projects?
2. What legal or procedural instruments would help ensure compensatory greening, ecological restoration, or corridor-level green infrastructure standards?
3. What recommendations would you give for improving the integration of mobility, environmental quality, and public-space function in future corridor projects?

Probe examples: specific project examples, planning document references, agency coordination mechanisms, design standards, monitoring practices.

4. Focus Group Discussion (FGD) Guide

• Target participants: Residents, traders, daily pedestrians, transport users, and community representatives within high-impact zones.

• Suggested group size: 6-10 participants per group.

• Suggested duration: 45-60 minutes.

Opening script

Thank you for joining this discussion. We are exploring how recent road corridor development has affected greenery, pedestrian comfort, environmental conditions, and daily life in this area. There are no rights or wrong answers. Please speak freely and respectfully. Your responses will be kept confidential and used only for academic purposes.

Theme 1. Access, use, and social value of green/open spaces

1. How did people in this area previously use nearby trees, shaded edges, or open spaces in daily life?
2. Have these spaces changed in size, quality, access, or usefulness after the corridor development?
3. Which groups were most affected by the loss or improvement of such spaces?

Theme 2. Environmental and daily livability impacts

1. What changes have you noticed in heat, shade, wind, dust, noise, or air quality?
2. How does rainfall now affect the area? Are there visible problems with runoff, puddling, or drainage?
3. Has walking in the area become easier, safer, or more difficult than before? Why?

Theme 3. Perception of modernization and future preferences

1. What do you see as the main benefits of the recent road developments?
2. What do you see as the major losses or negative consequences?
3. What features should be added in future projects to make the area greener, more comfortable, and more socially useful?