ETHIOPIA INSTITUTE OF ARCHITECTURE BUILDING CONSTRUCTION AND CITY DEVELOPMENT

ASSESSMENT OF URBAN TREE CANOPY COVER: CASE OF HAWASA CITY

BY
GEMEDA MEKURIA HABTE

THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE MASTERS OF SCIENCE IN URBAN DESIGN AND DEVELOPMENT.

ADVISOR
WONDWOSEN DEBEBE (PHD CANDIDATE)

APRIL, 2024
ADDIS ABABA, ETHIOPIA

Assessment of Urban Tree canopy cover: case of Hawasa city

Gemeda Mekuria Habte

Advisor: Wondwosen Debebe (PhD candidate)

Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements of the Masters of Science in Urban Design and Development.

April, 2024
Addis Ababa, Ethiopia

Assessment of Urban Tree canopy cover: case of Hawasa city

Gemeda Mekuria Habte

Approved by Board of Examiners

Name	Signature	Date
Wondwosen Debebe (PhD candidate) Advisor	------------------------------------	-------/-------/--------
Dr. Kalkidan Asnake External Examiner	------------------------------------	-------/-------/--------
Ass. Professor Nebyou Yonas Internal Examiner	------------------------------------	-------/-------/--------
Dr. Abunu Arega Chairperson	------------------------------------	-------/-------/--------
Dr. Dagnachew Adugna Post Graduate Program Director	------------------------------------	-------/-------/--------

Table of Contents

List of Equations vi

List of Figures vi

List of Tables vii

Acronyms viii

Abstract xi

CHAPTER ONE INTRODUCTION 1

1 Background 1

1.1 Statement of the problem 2

1.2 Objective 3

1.2.1 General Objective 3

1.2.2 Specific objective 3

1.3 Research Question 4

1.4 Scope of the study 4

1.5 Limitation 4

1.6 Significance of the study 5

CHAPTER TWO LITERATURE REVIEW 6

2 Conceptual Framework 6

2.1 Tree Canopy Assessment Method 8

2.2 Presentation Method 10

2.2.1 Tree Canopy and Urban Land use 11

2.2.2 Tree Canopy Biometrics 13

2.2.3 Urban Heat Islands (UHIs) 16

2.2.4 Albedo 18

2.2.5 Air pollution removal by urban trees canopy 20

2.2.6 Reduction of Surface Runoff by Urban Trees Canopy 22

2.2.7 Tree Characteristics and Species Found in Hawasa city 24

2.3 Case Study 31

Singapore has implemented various strategies to cool down its cities, including: 31

2.3.1 Vegetation: 31

CHAPTER THREE MATERIAL AND METHOD 41

3 Study Area Description 41

3.1.1 Location Map 42

3.1 Research design 43
3.1.1 Method of Data Collection 44
3.1.2 Data Analiysis: 45
3.1.3 Carbon in Tree 47
3.1.4 Rainfall Interception by Trees 48
3.1.5 Albedo of the Tree 49
CHAPTER FOUR RESULT 50
4 Hawasa City Canopy Assessment 50
4.1.1 Tree Benefits Estimate: Carbon 52
4.1.2 Tree Benefit Estimates: Air Pollution 53
4.1.3 Tree Benefit Estimates: Hydrological 55
4.2 The tree species found in Hawassa city, Ethiopia 57
4.3 Street Tree and Characteristics 58
4.4 Estimate The reduction Strategy for Carbon Dioxide, Air Pollution and Storm water Impacts. 59
4.4.1 Tree Benefits (Benefits are based on USDA Forest Service research) 59
4.5 Estimated average annual emission of Greenhouse Gases (GHG) for Hawasa City and Reduction Strategy 61
4.6 Rainfall Interception by Trees and Runoff Reduction Strategy 63
4.7 Urban Heat Islands Reduction Strategy (UHIs) 64
4.7.1 Albedo of the Tree Type 64
4.7.2 Solar Geometry Calculation for Hawasa City 65
4.7.3 Light-leafed tree 66
4.7.4 Darker-leafed trees 68
CHAPTER FIVE 70
5 DICUSSION 70
5.1 Summary of Finding, Conclusion and Recommendation 73
5.1.1 Tree planting framework and strategy to improve climate, air pollution, health and urban heat in vulnerable location of Hawasa city. 73
REFERENCES 78
6 ANNEXES 82
6.1 iTree analysis modeling for Tree canopy cover of Hawasa city 82
6.2 High Resolution Satellite Image extraction for Hawasa city 82
7 PUBLISHABLE ARTICLE 83
References 98

List of Equations

Total tree height = DB + BC = AB (tanΘ1 + tanΘ2)………………………… ....Equation 1

GW = r^2 x h Green Weight (GW)……………………………………….............Equation 2

DW = GW X 0.5 Dry Weight …………………………………………………….Equation 3

C = DW X 0.5 Carbon Storage (C)……………………………………………..Equation 4

NTS =TNE x %LPE/SCT…………………………………………………………Equestion 5

RF = $\pi r^2 h$ Rainfall interception by tree…………………………………………....Equation 6

Intercepted RF = RFI X Area for a single tree *Canopy* to intercept……………..……..Equation 7

Reflected solar radiation = (albedo of the tree) x (solar radiation on the tree)

Solar radiation on the tree = (solar constant) x (cosine of the solar zenith angle)

List of Figures

Figure 1: Urban Heat Islands profile---17

Figure 2: Locational Map of Hawasa City Administration (2007 E.C)------------------------------42

Figure 3: Research Structure---43

Figure 4: Land Use Map of Hawasa City (Source Hawasa City Administration, 2007 E.C)-----44

Figure 5: Tree Height Diagram---47

Figure 6: Rainfall Interception Diagram---48

Figure 7: Tree Canopy Cover Assessment Map of Hawasa city-------------------------------------50

Figure 8: Tree Canopy and Land Cover Data Summery of Hawasa city----------------------------52

Figure 9: Hawasa city street Network; source Hawasa city Administration-------------------------58

Figure 10: Estimated average annual emission of Greenhouse Gases (GHG) for Hawasa City--- 61

List of Tables

Table 1: Tree Characteristics and Species Found in Hawasa city-------------------------------------24

Table 2: Land Cover class of Hawasa City (Data analyzed Using iTree ----------------------------51

Table 3: Tree Benefits Estimate to reduce Carbon in Air for Hawasa city (Data analyzed Using iTree) --52

Table 4: Tree Benefit Estimates to reduce Air Pollution for Hawasa City (Data analyzed Using iTree)---53

Table 5: Tree Hydrological Benefit Estimates for Hawasa city (Data analyzed Using iTree)-----55

Table 6: Tree Benefits of Hawasa city (Benefits are based on USDA Forest Service research) --60

Table 7: Solar geometry calculation of the Hawasa city---66

Acronyms

CCEP - Canopy cover at the edge of pavement

UTC -Urban Tree Canopy

LiDAR- Light Detection and Ranging

FMB - Forest measurement and biometrics

UHI -Urban Heat Island

VOC -Volatile organic compounds

USGS-United State Geographic System

GIS - Geographic Information System

PM - Particulate Matter

GHG - Greenhouse Gases

NTS- Number of tree Species

TNE - Total Number of Emission

LPE - Land use Pollution Emission

SCT -Sequestration Capacity of Tree

RFI -Rainfall Intensity

TCC - Tree Canopy Cover

TC – Tree Canopy

Acknowledgement

I would like to express my deepest gratitude to all those who have supported and contributed to the completion of this research paper.

First, I am immensely thankful to my GOD Almighty. Secondly, I am thankful to my advisor Wondwosen Debeb, whose guidance, expertise, and encouragement were instrumental in shaping the direction of this research. Your insightful feedback and continuous support have been invaluable throughout the entire process.

I extend my sincere appreciation to EiABC for their financial support, which made this research possible.

Lastly, Special thanks go to my family and friends for their unwavering support and understanding during the demanding phases of this research. Your encouragement provided the emotional sustenance needed to persevere.

Declaration

I hereby declare that this thesis entitled "Assessment of Urban Tree canopy cover: case of Hawasa city," has not been presented for degree in any other university. The other books, articles, journals I have used are acknowledged at the respective place in the text.

Name: Gemeda Mekuria Habte

Signature: ------------------------------

Date: --------------------------------

This thesis has been submitted for examination with my approval at university advisor

Name: Wondwosen Debebe (PhD candidate)

Signature: ------------------------------

Date: ------------------------------

Abstract

Urban areas face increasing challenges related to environmental sustainability, with the inadequate of green Infrastructure and tree canopy coverage being a pressing concern. This study focuses on the assessment of tree canopy coverage in Hawasa City, offering crucial insights into the multifaceted benefits it provides. Methodology involves iTree, remote sensing, GIS mapping, and field surveys, the research reveals that the total tree canopy cover in the city is approximately 18%. This canopy cover serves as a significant carbon sink, storing and sequestering around 565,160 tons of carbon, thereby contributing to the mitigation of atmospheric carbon dioxide levels. Additionally, the study finds that the existing tree canopy generates substantial economic savings, amounting to $27,321,773 per square mile per year, by reducing energy costs associated with indoor cooling.

Moreover, the environmental advantages extend to storm water management, with a reduction of 135,590 liters of runoff per square mile per year. This not only aids in preventing property damage but also results in a significant cost savings estimated at $320 per square mile per year. The study further highlights the role of tree canopy in mitigating urban heat island by absorption heat energy that come from the sun, revealing that in each square meter of land, light-leafed trees absorb only 615.18W of the solar heat energy and reflecting 307.59W back into the atmosphere.

These findings underline the holistic benefits of preserving and enhancing tree canopy coverage in urban areas, providing a foundation for evidence-based decision-making by city planners and policymakers. The methodologies employed in this study offer a replicable framework for similar assessments, encouraging the adoption of sustainable practices. Therefore, the Hawassa city administration should set tree cover targets to achieve the desired balance between green and grey infrastructure and enhance the climate resilience level of the study area.

CHAPTER ONE INTRODUCTION

1 Background

Tree canopy cover or more precisely, the ·amount and distribution of leaf area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so do the benefits afforded by leaf area: climate control and energy savings; improvement of air, soil and water quality; mitigation of storm water runoff; reduction of the greenhouse gas carbon dioxide; provision of wildlife habitat; and increased real estate value and community vitality (Scott E. Maco and E. Gregory McPherson, 2002).

The extent of community tree canopy cover is one indicator of urban forest sustainability (Clark et al. 1997). Generally, more canopy cover is presumed better. However, in terms of the fraction of ground surface covered by tree crowns, defining the ideal canopy cover in any given community has proven a difficult task because of differences in resource structure, land-use patterns, climate, management practices, and community attitudes. American Forests (2002) identified canopy cover targets by land use 15% in downtown and industrial areas, 25% in urban residential and light commercial areas, and 50% in suburban residential areas). Periodic canopy cover analysis can help communities assess the effectiveness of measures aimed at preserving existing trees and increasing stocking levels (Bernhardt and Swiecki 1999).

Canopy coverage over paved surfaces has been linked to benefits as a cost-effective means of mitigating urban heat islands (Akbari et al. 1992; Asaeda et al. 1996), reducing emissions of hydrocarbons involved in ozone formation (Scott et al. 1999), control of storm water runoff (Xiao et al. 1998), and increasing pavement longevity (McPherson et al. 1999). Most cities, however, do not have a street tree performance ordinance that specifies a Percentage of canopy cover over public streets and sidewalks as they might for other paved areas, such as parking lots. For example, a Sacramento, California, U.S., ordinance, adopted in 1983, requires parking lots to attain 50% shading coverage of the total paved area within 15 years after development (Sacramento City Code §17.64.030(H)). Street tree planting regulations typically require one tree per residential lot or every 10 m to 20 m of street frontage (Abbey 1998)'((Scott E. Maco and E. Gregory McPherson, 2002))'.

Determining appropriate tree canopy cover over city streets and sidewalks is complicated because planners must consider the dynamics of stand development, as well as factors such as species composition and land use. For example, street tree stands are frequently even aged for 20 to 60 years after planting. Canopy cover gradually increases to a maximum just before senescence and age-related mortality begin to reduce total cover. If trees are selectively removed and replaced over many years with similar species, canopy cover can be maintained at a sustainable level, where a prevalence of young trees is poised to fill the void left by the continued loss of old trees. Alternatively, large numbers of trees may be removed and replaced, resulting in a more drastic loss of cover and subsequent recovery. For a neighborhood stand, the amount of canopy cover achieved by first generation street trees is likely to be greater than it -will be after the population has achieved a more diverse and stable age structure. Recognizing that neighborhood stands have different species compositions further complicates the issue (Scott E. Maco and E. Gregory McPherson, 2002). Therefore, the question remains how do communities assess appropriate street tree canopy cover?

The use of photogrammetry and remote sensing are two ways cities can analyze street tree canopy cover. Calculated by ground survey or through aerial photograph examination, an alternative proposed by Bernhardt and Swiecki (1999) uses an index based on canopy cover at the edge of pavement (CCEP). While useful for comparison over time, CCEP is a one-dimensional measure of canopy cover and cannot be used to estimate benefits that are directly related to area of canopy coverage (Scott E. Maco and E. Gregory McPherson, 2002).

This research examines the current canopy cover in Hawasa City, its distribution pattern, composition, and potential ecosystem services it provides. Based on the findings of this study, the region will be able to make informed decisions about enhancing urban green spaces and promoting sustainable development.

1.1 Statement of the problem

Urbanization drives multi-dimensional process, it changes environment, health and socioeconomic structure. It also change land use and land cover and contribute to climate change. Therefore, promoting sustainable urban development is a key to limit natural landscape consumption and ensuring the wellbeing of population is the first priority for landscape planner and designer.

Hawassa City, like many rapidly urbanizing areas, is experiencing substantial changes in its landscape, with the expansion of infrastructure and built environments. The reduction in green cover, specifically the canopy cover, raises concerns about the potential consequences for environmental quality. As urbanization and environmental changes continue, understanding the current status of tree canopy cover of Hawasa city is vital for assessing the city's ecological Benefits. The proximity to the lake adds complexity; as it introduces unique environmental dynamics since sustainability of the lake depend on the natural environment. Urban land expansion influence the distribution and benefits of the tree canopy for the community and lake by exacerbating air pollution, Urban Heat Island, Runoff water. This study seeks to address the gap in knowledge concerning the extent, distribution and ecological advantages of tree canopy cover in Hawasa city, specifically exploring its interplay with the surrounding environment including Hawasa Lake. By comprehensively evaluating the tree canopy and its benefits, this research aims to provide valuable insights for urban planning, environmental conservation, and sustainable development, ensuring the resilience and well-being of both the city and its natural surroundings.

1.2 Objective

1.2.1 General Objective

To determine and quantify the extent and distribution of tree canopy cover within the city of Hawasa and to set goal for urban tree canopy cover.

1.2.2 Specific objective

1. To determine the existing canopy cover percentage within Hawasa City.
2. To Analyzing the role of tree canopy cover in capturing and filtering air pollutants, including particulate matter and gases (SO_2, CO, NO_2, SO_2,) thereby enhancing overall air quality.
3. To Investigating, the capacity of the tree canopy to provide shade and reduce surface temperatures and creating microclimates that enhance outdoor comfort for residents.
4. To Evaluating the ability of tree canopy cover to reduce surface runoff and enhance storm water absorption, thereby mitigating the risk of flooding and Ground water recharge.

5. To provide recommendations for improving canopy cover and tree composition to enhancing the urban tree canopy cover benefit.

1.3 Research Question

1. What is the current percentage of urban tree canopy cover of the Hawasa city?
2. How does quantifying urban canopy cover reduce carbon dioxide concentration in the air?
3. How does quantifying urban tree canopy cover prevent urban heat island?
4. How does quantifying urban tree canopy cover reduce urban runoff?
5. What kind of tree species suitable for the urban tree canopy cover?

1.4 Scope of the study

The scope of the study is limited both by geographical location of the city and by the subject matter. The focus of the study is bound in the layer of spatial attributes of the tree canopy cover of Hawasa city.

This research examines the current tree canopy cover in Hawasa city and potential ecosystem services it provides for managing future plantings.

1.5 Limitation

Age can introduce limitations to the assessment of canopy cover. Canopy cover assessments conducted at a single point in time may not capture the dynamic nature of canopy development with age. Long-term monitoring is necessary to understand how canopy cover changes over time as vegetation matures.

Therefore, future research should focus on implementing long-term monitoring programs that track canopy cover changes across different age classes of vegetation. This research would provide valuable insights into the temporal dynamics of canopy cover, helping improve our understanding of ecosystem development, resilience, and responses to environmental changes. Additionally, exploring innovative methodologies and technologies for continuous monitoring could further enhance our ability to capture these dynamics accurately.

1.6 Significance of the study

This paper is useful to city planners, designers as well as decision makers in raising awareness of urban tree canopy cover and its effect on urban climate, environment and social health.

This Research quantifying the structure, function, and benefit of urban tree canopy. It can be used by potential partners to design urban space for trees and evaluate return on urban forest investments, urban dwellers to use limited resources more cost effectively and government as well as nonprofit organizations to instruct citizens about the value of trees. Therefore, it is critical for stakeholders to understand urban tree canopy cover of Hawasa city and its goal to reach cities future plantings need.

CHAPTER TWO LITERATURE REVIEW

2 Conceptual Framework

The first development of the Urban Tree Canopy (UTC) Assessment start in 2006 when the U.S. Forest Service first introduced iTree. Initially designed to comprehend the extent and dispersion of tree canopy in Baltimore, Maryland, the UTC Assessment has since evolved into a widely adopted practice. Its application extends beyond national borders, with assessments conducted in hundreds of cities across the United States and internationally (U.S. Department of Agriculture, 2019).

In 2003, the U.S. Forest Service, a branch of the Department of Agriculture (USDA,2019), allocated funding for a study on the Urban Tree Canopy (UTC) in the City of Baltimore. This research, led by the Maryland Department of Natural Resources, utilized 1-meter resolution satellite imagery (Irani and Galvin 2003). The collected data was integrated into the city planning department's Geographic Information System (GIS), offering insights into the distribution of Baltimore's 20 percent overall canopy cover across neighborhoods, zoning classifications, and various land use types, including residential, commercial, and transportation corridors. This comprehensive analysis identified existing and potential UTCs at the parcel level, presenting information in a format and resolution suitable for guiding planning and planting decisions. The data served as a valuable resource for directing priorities based on community capacity for stewardship and other relevant considerations (Locke et al. 2013).

Utilizing this data, the city formulated a prioritized tree planting plan, aiming to achieve a tree canopy goal of 40 percent by 2030, as outlined in Baltimore's 2009 Sustainability Plan. This initiative was spearheaded by a mayor's effort, involving collaboration among various city agencies and nonprofit organizations, successfully mobilizing public interest and participation to reach the established goal (J. Morgan, 2013)

The impact of the Baltimore study extended beyond the city, giving rise to a new Urban Tree Canopy (UTC) assessment industry. The U.S. Forest Service conducted assessments in Washington, DC, New York City, NY, and Philadelphia, PA. In each case, these assessments led city-elected officials to establish tree canopy goals for their respective municipalities. The accuracy of tree canopy quantification saw consistent improvement through the application of object-oriented classification and the incorporation of Light Detection and Ranging (LiDAR) technology. Developed by the University of Vermont Spatial Analysis Laboratory, this technology distinguished trees from shrubs and accounted for trees in shadow. Notably, a reevaluation using this advanced method revealed that Baltimore's original canopy cover was approximately 27 percent, surpassing the previously estimated 20 percent (O'Neil-Dunne 2009).

From 2006 to 2012, research activities were duplicated across the environmentally sensitive Chesapeake Bay Watershed and various cities throughout North America. These studies not only provided valuable data but also facilitated groundbreaking scientific exploration into the social factors associated with tree canopy presence on private residential properties. This inquiry uncovered the significance of lifestyle in elucidating the spatial distribution of this vital natural resource (Troy et al. 2007).

Around 2010, the private sector actively engaged in the application of Urban Tree Canopy (UTC) assessment technology. Collaborating with forward-thinking local government officials, consultants experimented with the integration of UTC assessments and i-Tree modeling tools (www.itreetools.org) to inform localized planting priorities. This marked the commencement of efforts to prioritize and potentially enhance canopy cover, aligning with goals related to air quality improvement, carbon capture, storm water management, and energy conservation.

Urban tree canopy provide numerous ecosystem services that become apparent at different scales. At the larger scale, we look to forests to reduce storm water runoff, improve regional air quality, reduce stream channel erosion, reduce summer air and temperatures, and provide habitat for terrestrial and aquatic wildlife. At the community and parcel scale, we look to trees to improve public health, decrease home and office energy usage, provide recreation, buffer wind and noise, provide shade, and increase community desirability. While we may not think of city trees as a typical forest, these trees provide valued services to our daily lives. By increasing tree cover in urban areas we can decrease the volume of storm water runoff, reducing air pollution, lowering city temperatures, enhancing property values, providing wildlife habitat, and adding to the beauty, livability, and desirability of our communities. It is important to understand that urban development is increasing rapidly and as urban areas grow, so will their contribution to water, air and temperature quality problems in the urban environment. Urban tree canopy (UTC) enhancement can help mitigate some of the harmful effects of an increasingly developed built up urban landscape by providing many of the ecosystem services that forests would have provided. While a few communities have instituted smart growth strategies, which help mitigate urban sprawl, fewer still have developed land cover strategies like UTC to help mitigate the environmental effects of newly urbanized areas. Urban Tree Canopy (UTC) holds significant potential in reducing impact of urbanization on the environment (Raciti, 2006).

Urban canopy cover is the amount of area that is covered by trees in urban landscapes. It plays an important role in providing a number of ecosystem services to urban populations including improved air quality, reduced noise levels, reduced heat stress, and improved biodiversity levels, flood mitigation and mitigation of localized climate change effects. In order to assess the current amount of urban canopy cover as well as its effects on urban environments, various approaches have been employed in the past. The Assessment of Urban Tree Canopy (UTC) is a critical component of understanding the current state of urban ecosystems and managing future plantings. Urban tree ecosystem services are produced in a diverse set of habitats, including: green spaces, such as parks, urban forests, cemeteries, vacant lots, gardens and yards, campus areas, landfills. Additionally, they extend their benefits to blue spaces such as streams, lakes, ponds, artificial swales, and stormwater retention ponds. Urban tree canopy ecosystem services are generally characterized by a high intensity of use due to a very large number of immediate local beneficiaries (Elmqvist, 2015).

2.1 Tree Canopy Assessment Method

The Assessment of a UTC typically include estimating the areal extent, species composition, species diversity and health condition of existing vegetation. In twenty first century, advances in remote sensing technology have enabled the study of UTC at unprecedented detail and accuracy. A key system and tool to assessing urban canopy cover is through remote sensing techniques (e.g airborne LiDAR), which can be used to map out composition and distribution of vegetation across entire cities and regions. Remote sensing has been widely applied in both high-resolution and coarse resolution assessments with various results reported for different locations. For example, a high-resolution assessment conducted using LiDAR data for Seattle, Washington finding a moderate amount of tree cover at 44% and variations between neighborhoods at fine scales due to age structures and development patterns. In Atlanta Georgia assessed total tree cover from aerial photography with many areas reported as 22-45 %. However when conducting extreme top analyses, higher values have often been found ranging from 53-90% (City of Seattle office of Sustanability, 2021).

Aerial photography has also proven to be an effective tool for estimating canopy cover over time periods where historic photos can allow for long term back casts or estimates regarding canopy dynamics within certain areas or cities. These data can also provide valuable information about changes to the overall urban environment relating to population demographics, land use changes or even environmental impacts related to other factors such as drought or taxation allocations which show impacts over large scales with years rather than months. Finally, aerial photographs can show how tree planting policies are implemented in different spatial patterns. Drone technology has become increasingly popular in recent times due to its low cost and wide range applicability and while the accuracy is lower than traditional methods it offers more targeted ground level assessments allowing better estimates directly beneath trees where many environmental benefits occur (R.J. Hall, 2003).

i-Tree Canopy uses Google Maps aerial imagery and allows the user to use a random sampling process to easily estimate tree cover and classify ground cover types. i-Tree Canopy is a point-based method, providing a statistical sample rather than a spatially explicit census of the landscape. The user creates a defined project area directly on the online map; i-Tree Canopy then generates random sample points within the project area. Users are able to zoom in on each point and choose from a list of cover types based on the map image. This canopy cover tool can provide excellent accuracy and valuable for broad or general information needs, since results are in the simple form of a percent tree cover for the project area and information. The extent of tree presence throughout a city can be effectively estimated through the measurement of city-wide tree canopy cover assessment using iTree. This assessment is not only simple and quick but also highly reproducible. Employing repeat observations offers a cost-effective approach to monitoring tree populations, establishing targets, and evaluating the success of tree planting programs (Kieron J. Doick, 2017).

One of the major challenges to assessing UTC is determining the measurement method. However several methods can be used including ground surveys or aerial analyses with various scale resolutions generated through remote sensing such as digital orthophotography (DOP), LiDAR data or intrusive methods such as quantitative vegetation sampling Using DOP for UTC assessment has been widely applied for large-scale studies. However, it may not accurately represent structural attributes like tree height or condition due to its limited resolution. An increasing use in land-use land cover mapping has been LiDAR measurements, which can provide highly detailed information on structure and topography but may not identify some tree types due to their crown shape or size. Recent studies made in USA "Comparing ground and remotely sensed measurements of urban tree canopy in private residential property" have combined both LiDAR and DOP analysis to quantify more accurately UTC features. Among multiple applications, the integration allows an examination of tree density beyond what DOP can achieve by itself via 2-dimensional classifications between trees and non-tree classes with remarkable efficiency for semi-automated feature identification from high-resolution aerial imagery when combined with ancillary datasets such as road extents from base GIS layers. These techniques offer great promise in being able to capture detailed information on a city's tree canopy while allowing fast updates over time with innovative applications that leverage open source software libraries like White box GAT toolsets. Other methods used include assessing demographic factors associated with UTC using census data such as educational attainment, ethnicity compositions and poverty levels that allow urban ecologists to better understand spatial temporal dynamics of populations living under different urban densities and their access benefit from green spaces (Blaz Klobucar et al. 2021).

2.2 Presentation Method

Reporting methods used in assessment also plays a key role in effectively reaching stakeholders. An analysis of New York City's tree canopy based on land-cover data derived from high-resolution remotely sensed data found that 39,284 acres of the city were covered by tree canopy, representing 21% of the total land area. An additional 43% (81,982 acres) of the city could theoretically be modified to accommodate tree canopy. In the Possible TC category, 25% (45,531 acres) of the city was classified as Impervious surface and another 18% was Vegetated Possible TC (33,976 acres). Vegetated Possible TC, or grass and shrubs, is more conducive to establishing new tree canopy, but establishing tree canopy on areas classified as Impervious Possible TC will have a greater impact on water quality and summer temperatures. Using assessment data outcomes, local politicians nonprofit organizations alike join hands work together creating more livable Green infrastructure intensive cities. Additionally proactive publication transparently documenting progress increase visibility amongst decision makers encourage best practice sharing Asset

Management and private industry play greater role in environmental conservation processes (O'Neil-Dunne, 2012).

In conclusion, it is clear that there are a different ways available to measure urban canopy cover at both at coarse resolution imagery (from drone photogrammetry) and fine scales (such as point clouds from GIS), however each method has its own advantages and limitations depending on location. Combining multiple approaches may help reduce uncertainty whilst providing informative insights into how developments affect sustainability outcomes. UTC assessment involve much more than remote sensing, a combination of GIS layers, canopy goal setting, or a set of tree planting prioritization scenarios. For real success, the UTC assessment must be considered a process that matches the goals, needs, capabilities, and resources of a community with an analysis of the best ways to achieve urban forestry objectives. The steps in the process should lead from initial goal setting through assessment, analysis or prioritization, and implementation to monitoring and evaluation-all of these with the input and involvement of stakeholders and partners. The partnerships and relationships formed during a UTC assessment project provide long-term benefits to both the urban forest and the broader community far beyond the simple act of planting a tree (Dr. James R. Fazio, 2016).

2.2.1 Tree Canopy and Urban Land use

Land use is an overriding determinant of urban tree characteristics, including distribution, coverage, canopy configuration and composition. The land use pattern reflects the interplay between natural factors, and more importantly human decisions. The type and intensity of land use determine the availability of growth spaces (opportunities) or their exclusion (constraints). The quality of the growth spaces, by virtue of stresses to plant growth, is also a function of land use. The spaces could either be left in the form of residual niches by default, or by design. Different land uses furnish spaces with range of sizes and shapes that set limits on and regiment the configuration of tree cover. The extent and the manner by which such spaces are utilized depend on another level of human decision. The commercial, high-density residential, and industrial and storage land uses are the most densely built-up with over 95%. The TCC is extremely low in this land use. The character of the vegetation is also shaped by the subsequent management system, which denotes interventions on ecosystem dynamics (JIM, 1989).

Examining alternative theories regarding the connections between urban residential lands and vegetation cover goes beyond academic exploration. Identifying the theory that most accurately elucidates the interplay among factors such as population density, socio-economic status, group identity, and private residential canopy cover holds profound implications for shaping policies, plans, and management strategies to advance urban sustainability. For instance, if population density emerges as the primary determinant of vegetation distribution, decision makers would likely prioritize interventions in land use planning and urban design. Conversely, if social stratification proves to be the key explanation, decision makers would need to address environmental investment patterns and processes crucial for promoting environmental justice. Alternatively, if a luxurious lifestyle is the chief factor influencing vegetation distribution, decision makers might consider subsidies like free giveaways or tree rebates to enhance tree availability. However, the research findings indicate that lifestyle is the most compelling explanation for the distribution of trees on residential lands. This doesn't diminish the importance of land use planning, urban design and environmental justice, or cost considerations. Instead, it underscores the significance of understanding lifestyle factors in tailoring effective strategies for fostering greenery in residential areas (Grove et al 2014).

Uncontrolled urbanization impact is a major catalyst driving changes in land cover dynamics in Ethiopia. The lack of knowledge regarding the distribution and trends of different urban land surface covers in Ethiopian cities and towns obstructs environmentally sustainable urban planning efforts. A study by Gebreyesus et al.2022, focused on the dynamics of land surface cover in built-up areas and its implications for sustainable urban planning in Hawassa city sheds light on various land surface cover types and their changing patterns. This research examines the period from 2011 to 2021, utilizing i-Tree canopy analysis and Landsat 5 (TM) and Landsat 8 (OLI) images for 2011 and 2021, respectively. The findings reveal that bare soil dominates the land surface cover at 23.4%, followed by tree canopy cover at 21.4%, with impervious roads and water bodies covering the smallest areas at 3.4% and 1%, respectively. Over the decade, most land surface cover types experienced positive growth, notably tree covers, which increased by +9.8%. The exceptions were bare soil and herbaceous cover, which saw significant declines of -34.6% and -2.8%, respectively. The study demonstrates that the increment in tree cover has led to a decline in both average and maximum Land Surface Temperature over the specified period. This inverse correlation between increasing tree cover and land surface temperature suggests that integrating green coverage into urban expansion can mitigate heatwaves in rapidly growing urban areas. Consequently, the city administration is urged to establish tree cover targets to achieve a balanced blend of green and grey infrastructure, thereby enhancing the climate resilience of the studied area (Gebreyesus et al. 2022).

In conclusion the study made in Hawasa city by Gebreyesus et al. 2022. Show that 21.4% of the land cover was not only tree canopy cover but also grass land and shirubs. Therefore this will make it imposible to understand the Exact number of Tree canopy cover of the Hawasa city.

2.2.2 Tree Canopy Biometrics

City tree biometrics is the exercise of measuring and recording the characteristics of Tree in urban environments, commonly for studies or tracking purposes. Tree biometric measurements provide records approximately a tree's age, species, situation, relative abundance and influences on its environment. Examples of biometric measures consist of trunk diameter at breast Height (DBH), crown size and crown situation including stem deformities, decay or disease presence. The motive of amassing those information are to assist urban planners in both making knowledgeable decisions when dealing with an city wooded area and monitoring adjustments over the years(Scott et al 2003).

Forest measurement and biometrics (FMB) programs have played a central role in North American forestry education for over a century, dating back to the establishment of the Biltmore Forest School. Throughout this time, the field of forestry has undergone significant transformations. It has evolved to embrace a much broader view of the goals for urban forest management: more types of forest outputs are important, not just timber. In addition, it has become increasingly quantitative in its approaches to research and management. Rising forest values increase the demand for accuracy and precision in quantitative approaches for management prescriptions and projected outcomes, necessitating quantitative approaches. Both trends have magnified the importance of FMB as tools of forestry science. Forest measurement focuses on collecting, summarizing, and analyzing information at tree, stand, and forest levels. Forest biometrics applies mathematics and statistics to efficiently analyze and quantify past, present, and future attributes at all three levels. FMB offers valuable information for decision making because it provides quantitative measures of current resources, means to compare differences between alternative experimental resource treatments, and methods to project future outcomes of management practices (Temesgen, 2007).

Trees play many vital roles inside cities, which includes provision of shade that can enhance air clearing, water retention in soil and presenting habitat for natural world. Measuring new trees present process for management, in addition to the ones broken due to storms or other activities is vital to keep this ecosystem service. Moreover, considering the capacity benefits related to city green infrastructure tasks including typhoon water runoff prevention and habitat conservation. Understanding important attributes about existing trees is important for managing and monitoring urban ecosystems (England Forestry Commission , 2012).

Measurements (Pace, 2022)

Urban tree biometric measurements normally contain making direct bodily measurements of trees, which are developing in urban environments. These commonly include the subsequent:

1. Tree diameter or circumference at breast height (DBH): this measures the width of the tree trunk, usually taken four.5 feet from the floor. It is a excellent indicator of tree length.

2. Crown spread: this measures the horizontal distance throughout the widest factor of a tree's cover and is used to estimate its universal length.

3. Height: trees can be measured from four different points to estimate its general top, which includes from base to tip, from crown base to crown tip, and with the aid of estimating trunk height for bushes with multiple trunks.

4. Volume: the quantity of any given tree may be anticipated the use of mathematical formulation based totally on a mixture of factors which include dbh, top, and shape thing.

5. Bark thickness: this provides an indication of how sturdy and healthful a tree is, considering thicker bark might also indicate that it has strong defaces towards sicknesses or insect attacks as compared to thinner bark.

6. Branch span: the maximum span between two branches on a unmarried facet of a tree can indicate its normal health. A much broader branch span indicates more freedom for boom even as narrower or buds recommend limited or contained boom.

Urban tree species display considerable variation in biometrical traits regardless of climate or geographic location. Common street tree species often come from multiple sources that vary in size and shape due to genetic diversity or environmental conditions; hence it may be expected that (biometric) variability will exist within a particular species planted in a local population. This can translate into significant impacts on an urban forest's ability to deliver multiple services and mitigate detrimental effects like flooding and heat stress phenomena stemming from climate change (Ziemiańska, 2017).

Tree height is one measurable quality that influences both aesthetic appeal as well as performance related qualities such as carbon storage capacity (larger trees store more carbon). Consequently, taller trees experience increased levels of air temperature cooling compared to smaller ones since they draw down more cool air from higher upwind layers, which may enhance human health during hot days. In all cases however, tall trees present the risk of decreases mitigation performance when subjected to extreme winds, which cause upright trees stronger resistance than lower ones. Additionally Biometric measurements such as diameter at breast height (DBH) are key variables influencing many functional properties related to recreation spaces such as affording shade and also otherwise ecological factors ranging from hydrological function sand biodiversity by affecting carbon cycling rates. DBH represents an indirect measurement of a tree's age but also has implications for structural stability against extremes winds. Branches constitutes another important biophysical component exerting considerable influence over tree behavior by affecting intercepting stellar radiations , however there is need for further research replicating this relationship for concrete applications. Moreover, measurements regarding other branching parameters stems longevity ranking could inform studies anchoring gynecological knowledge. Furthermore changes in trunk volume over time convey some interesting insights about urban forest dynamic processes , focusing mainly on increasing dimension info gaps about early stage development; this implies deriving critical solutions enabling cities to ‘ grow ‘ stronger efforts towards maintaining sustained urban green cover (Arney, 2014).

2.2.3 Urban Heat Islands (UHIs)

Urban Heat Islands (UHIs) are phenomena characterized by increased urban surface and air temperatures in comparison to their surroundings. Several studies have shown that UHIs can increase urban temperatures compared to the surrounding rural environment by around 1-3°C on hot days. This difference can be further heightened within heavily built up areas, resulting in a noticeably warmer setting compared to open spaces outside the built environment(Sue Grimmond, 2010).

One of the primary contributors to UHI development is anthropogenic processes such as construction, industry, traffic and domestic energy use. The heat gained from these sources are known as 'heat fluxes' which accumulate within the city and cause its surface temperature to rise. Additionally, urban structures of tall buildings and narrow streets are better capable of trapping air pollutants and fumes such as smog leading them to be heated due to direct sunlight exposure (Ludwig et al., 2015) causing further contributions towards aggravated heat waves inside cities (Rao, 2022).

Studies have suggested that cities can get a greater mean temperature increase than rural areas depending on their geography, population size, infrastructure systems, and layout of built-environment. As urban populations continue to grow and construction becomes more intense in metropolitan regions, the problem of UHI has become even more urgent. Urban landscape design strategies can offer solutions such as lowering the amount of impervious surfaces, developing green spaces and vegetation, regulating building heights in residential zones composed mainly by low-rise buildings, as well as creating cooling towers or evaporative cooling systems in city centers(Nuruzzaman, 2015).

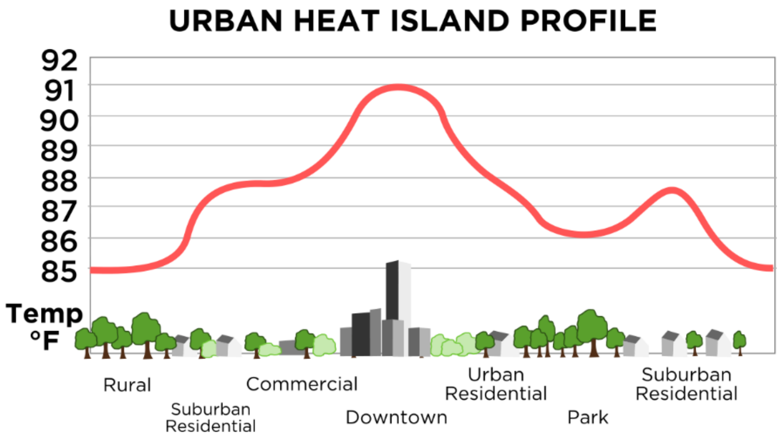


Figure 1: Urban Heat Island Profile (Source: MetLink, 2023)

The Urban Heat Island (UHI) has emerged as a prominent challenge, prompting the implementation of measures aimed at alleviation through urban planning. Various urban design strategies are employed to improve urban air quality and enhance outdoor thermal comfort by lowering surface temperatures. Mitigation approaches involve the manipulation of urban structure, including adjustments to building dimensions, spacing between structures, street widths, and spacing. Additionally, efforts focus on increasing urban cover, which encompasses fractions of built-up areas, paved surfaces, vegetated spaces, bare soil, and water bodies. Furthermore, the regulation of urban metabolism, addressing the heat, water, and pollutants generated by human activities, constitutes a crucial aspect of mitigating the Urban Heat Island effect (H.M.P.I.K. Heratha, 2017).

Enhancing urban shading through the integration of greenery proves to be a successful strategy, with trees playing a crucial role in mitigating air temperature through evapotranspiration. The presence of trees intercepts incoming solar radiation, preventing it from penetrating into street canyons and thereby offering shade and cooling benefits. The effectiveness of urban vegetation in cooling depends on factors such as foliage density and the cooling capacity of the plants (Teresa Zolcha, 2016).

Moreover, trees contribute significantly to the reduction of solar energy released to the atmosphere, as they utilize a substantial amount of solar energy for photosynthesis. Research findings demonstrate that photosynthetically active radiation decreased by 94% within 5 meters of the canopy in a Puerto Rican wet forest (S. Joseph Wright, 1994), and global radiation decreased by 53% within 6 meters of the canopy in a Malaysian rainforest (YODA, 1974)

Vegetation, through the processes of evapotranspiration and shading, can lower air temperatures by up to 5 °C. Additionally, trees play a role in reducing carbon dioxide (CO2) through carbon sequestration and decreasing ozone precursor levels in the air. This dual impact directly and indirectly contributes to the reduction of greenhouse gases (GHGs) in the surrounding microclimate (Akbari, 2019).

Many cities incorporate vegetative surfaces in their urban design, including trees along curbsides, center medians, living green roofs (Britta Janicke, 2014), green walls, green facades, and turf areas (such as turf paving, turf parking areas, and turf in urban gardens or parks). The potential benefits of such interventions are substantial, with the average maximum daytime temperatures in humid cities like Hong Kong potentially decreasing by 8.4 °C, the City of Athens by 10 °C, Riyadh by 3.4 °C, and Moscow by 1.7 °C through the strategic implementation of vertical greenery (Eleftheria Alexandri, 2007).

2.2.4 Albedo

The fraction of the incident radiation that is reflected from the surface is called the albedo. Albedo plays a major role in the energy balance of the earth's surface, as it defines the rate of the absorbed portion of the incident solar radiation. The portion of solar radiation not reflected by the earth's surface is absorbed by the soil or the vegetation that interacts with the incident radiation. The absorbed energy can increase the soil temperature or the rate of evapotranspiration from the surface of the soil-vegetation system. Some of the energy that is absorbed and transformed into heat is reradiated at a longer wavelength than the incoming radiation. That is why the peak terrestrial radiation occurs in the infrared spectrum while the peak incident radiation occurs in the blue–green portion of the visible spectrum. The albedo value ranges from 0 to 1. The value of 0 refers to a blackbody, a theoretical media that absorbs 100% of the incident radiation. Albedo ranging from 0.1–0.2 refers to dark-colored, rough soil surfaces, while the values around 0.4–0.5 represent smooth, light-colored soil surfaces. The albedo of snow cover, especially the fresh, deep snow, can reach as high as 0.9. The value of 1 refers to an ideal reflector surface (an absolute white surface) in which all the energy falling on the surface is reflected. The mean albedo of the earth system is 0.36 (Dobos,2005).

Albedo varies seasonally due to the changing sun angle. In general, the lower the sun angle the higher the albedo. Besides the sun angle, many of the surface characteristics have large impact on the albedo. The most significant factors affecting the soil albedo are the type and condition of the vegetation covering the soil surface, soil moisture content, organic matter content, particle size, ironoxides, mineral composition, soluble salts, and parent material. The type and the condition of the vegetation has a strong impact on the surface albedo. Forest vegetation with multilevel canopy has a low albedo because the incident radiation can penetrate deeply into the forest canopy where it bounces back and forth between the branches and leaves and are trapped by the canopy. The albedo for grassland and cropland ranges between 0.1 and 0.25 (Akbari, 2019).

The urban heat island (UHI) phenomenon is the most widely documented climatological effect of man's modification of the atmospheric environment, typically defined as the difference between the background rural and highest urban temperatures. Some studies assessed that the temperature increase may reach up to 10 °C. The intensity of the UHI depends strongly on the urban characteristics, the synoptic conditions, the local meteorological features, the type of urban materials and the presence (or lack) of green areas. Urban warming has serious energy and environmental impacts on cities and its residents (Federico Rossi, 2016).

The UHI may increase the energy consumption of a reference building and leads to a rise of CO_2 equivalent annual emissions for a cooling of up to 7%. Between 1950 and 2010 the total load increased by 3.5% for small offices; for medium offices the cooling load increased by 18%, and for large offices the total load decreased by 1.0%. According to the calculation of the total energy consumption for heating and cooling of a residential building, the total energy consumption for heating and cooling increased from 42.4 kWh/m2/year to 47.7kWh/m2/year from 1990 to 2000. The UHI, heating demand will be reduced while the cooling and electricity consumption demand will be higher in 2050, resulting in a 500% growth in CO2 emissions in city-center offices. By means of a carbon footprint analysis, Rossi et al. also calculated that the decrease of the performance of electronic and mechanical instruments could reach up to 25%. Furthermore, although the relationship between heat and mortality varies by location and population group, heat-related mortality during summer months is likely to become a dominant public health problem in the future due to the effects of climate change and will increase sharply over this century (Elena Morini, 2016).

2.2.4.1 Solar Geometry and Albedo

The earth's albedo is typically represented as the ratio of reflected electromagnetic radiation to the incident amount on its surface, often expressed as a percentage. This collective albedo is composed of countless individual surface albedos spanning its entirety. These surface albedos fluctuate throughout daylight hours based on the solar zenith angle. However, research on albedos commonly focuses on measurements taken near local noon. Kung, Bryson, and Lenschow (1964) conducted a notable study on seasonal albedos in North America, producing detailed maps delineating regional albedo averages over areas ranging from several hundred to several thousand square kilometers.

2.2.5 Air pollution removal by urban trees canopy

Air pollution poses a significant environmental challenge in numerous major cities globally. Urban trees play a role in contributing to ozone (O3) formation through the emission of volatile organic compounds (VOC) (W. L. CHAMEIDES, 1992). Nevertheless, comprehensive studies are demonstrating that urban trees, especially those with low VOC emissions, can serve as a practical strategy for mitigating ground level urban ozone and air pollution. This is achieved through tree functions such as air temperature reduction (transpiration), air pollutant removal (dry deposition to plant surfaces), and the reduction of building energy consumption, leading to decreased power plant emissions (e.g., temperature reductions, tree shade). Urban trees and shrubs possess the capability to effectively eliminate substantial quantities of air pollutants, leading to an enhancement in environmental quality and human health.

The removal of gaseous air pollutants by trees primarily occurs through uptake via leaf stomata, with certain gases also being eliminated through the plant surface. Once within the leaf, gases diffuse into intercellular spaces and may undergo absorption by water films to form acids or react with inner-leaf surfaces (Smith, 1990). Additionally, trees contribute to pollution removal by intercepting airborne particles. While some particles can be absorbed into the tree, the majority of intercepted particles are retained on the plant surface. These intercepted particles are often either released back into the atmosphere, washed away by rain, or dropped to the ground during leaf and branch fall. As a result, vegetation serves as a temporary retention site for numerous atmospheric particles (Nowak, 2006).

Urban trees are an important component of green infrastructure in cities. Trees have many environmental benefits and play a major role in reducing the amount of airborne pollutants. Through the process of photosynthesis, they can remove deposits of particles and gases that issue from various sources such as industry, energy production, agriculture, transportation, and construction (Mukherjee, 2018).

Air pollution stands out as a prominent environmental concern impacting communities and cities globally. Trees emerge as a potent solution for mitigating air pollutants, demonstrating the capacity to absorb substantial concentrations of contaminants released into the atmosphere, including particulate matter (PM), ground-level ozone (O_3), and harmful volatile organic compounds (VOCs). Empirical studies have consistently underscored the efficacy of this mechanism in lowering air pollution levels. For example, Yang Xing (2019) studied urban trees in Hong Kong park, using an ambient air quality monitoring station located near the study site, they measured changes in concentrations of PM2.5 over a five-month period during different seasons and analyzed their correlations with tree canopy coverage data at designated locations. Results showed that tree canopy coverage was correlated with PM2.5 reduction; when combined with other factors like wind speed fluctuations, this factor accounted for approximately 17% of PM2.5 reduction attributed to trees alone. Additional results from the authors revealed a functional relationship between canopy cover and pollutant reduction which suggested most of these gains could be achieved even with a modest amount of canopy cover and relatively smaller tree size than what generally exists in many urban parks and playgrounds today (Xinga, 2019).

In 1996, Washington DC conducted a significant study on urban air pollution. The air quality within the Washington Metropolitan Area failed to meet federal standards for ground-level ozone and particulate matter. While the primary solution for improving the region's air quality lies in reducing emissions of these pollutants, trees have proven effective in mitigating air pollution. Trees act by absorbing gaseous pollutants through the stomata on the leaf surface, and they can reduce street-level particulate matter by 60%. According to an analysis using the Urban Forest Effects Model (UFORE), trees in the District remove 490 metric tons of air pollution annually, translating to a benefit valued at $3.7 million per year in reductions in air pollution-related healthcare spending. Specifically, District trees are estimated to annually remove the following pollutants: 23 metric tons of carbon monoxide (valued at $32,000), 65 metric tons of nitrogen dioxide (valued at $645,000), 196 metric tons of ozone (valued at $1.9 million), 66 metric tons of sulfur dioxide (valued at $160,000), and 140 metric tons of particulate matter (valued at $928,000) (McAliney, 2013).

Urban trees can significantly improve local air quality by capturing and clearing a considerable amount of COx, $NO_{x,}$ and PM2.5 inhalable particles, which contribute the majority health risk from urban living, simultaneously providing further insights on canopy cover needed for considerable pollution mitigation gains. There is still more room for investigation concerning specific roles played by different tree types across geographical regions since diversity is important for achieving stable ecosystem benefits to combat chronic atmospheric problems afflicting many overpopulated cities across many nations. Therefore, research efforts should explore potential air purifying benefits through innovative methods like green infrastructure or distributed evaluation techniques used to aid decision makers on strategically locating planting sites within congested urban cores so sensible densities could be achieved overall offering long lasting positive effects related associated with clean natural environments (Ahmet Akay, 2016).

2.2.6 Reduction of Surface Runoff by Urban Trees Canopy

The canopies of urban trees play a crucial role in significantly diminishing surface runoff within cities, thereby mitigating the risk of flooding and preserving essential ecosystem services for countless urban residents. Surface runoff emerges when precipitation or melting snow traverses impervious surfaces like roads, sidewalks, or rooftops. This phenomenon results in the depletion of water volume and an accelerated flow rate, causing soil erosion and transporting pollutants into surface water bodies. Furthermore, an excess of runoff has the potential to overwhelm urban drainage systems, precipitating extensive flooding in city areas (William R. Selbig, 2021).

Urban trees play a multifaceted role in minimizing surface runoff through the interception of rainfall, influencing the evaporation and infiltration of retained water, enhancing air quality, decreasing atmospheric CO2 levels, and contributing to energy consumption reduction. One frequently discussed benefit of urban trees is their capacity to reduce surface runoff. In a study conducted by (Armsona, 2013) in Manchester, UK, runoff from three different plots covered with grass, asphalt, and equipped with tree pits was measured. The findings revealed that trees can decrease the runoff coefficient from asphalt surfaces by 38% in summer and 43% in winter. Similarly, research by (Xiao, 2011) in Davis, Canada, demonstrated that the strategic arrangement of trees and engineered soil on a parking lot led to an 89% reduction in runoff. Rainfall interception measurements under two deciduous tree species in North Vancouver, Canada, indicated that urban trees canopy can intercept an average of 50-60% of rainfall, thereby reducing runoff. Study conducted by (Livesley, 2014) in Melbourne, Australia, during the fall, observing runoff reduction ranging from 30 to 45%, depending on canopy density. Even in residential yards, where urban forests are common, a case study in North Carolina, USA, reported a runoff reduction of 9–21%. Simulation using the UFORE-Hydro model in Baltimore, USA, illustrated that introducing trees to 12% of impermeable areas could result in a 3% reduction in runoff. The SCSCN method, frequently employed for runoff reduction modeling, indicated a 1–5% reduction in a Swedish study. Moreover, Huang et al. integrated various components of existing models, presenting an approach for estimating the efficiency of trees in reducing urban runoff (Zabret, 2019).

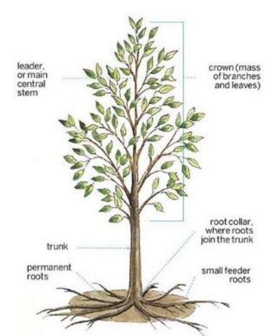
The recorded data on rainfall partitioning served as the basis for estimating the reduction in surface runoff resulting from the planting of selected tree species in the city of Ljubljana, Slovenia. Surface runoff calculations were conducted for a parking lot under two scenarios: one without trees and the other with trees, taking into account variations in seasonal characteristics (leafed and leafless), as well as dry and wet years, using values for gross rainfall and interception. In the wet season, the total runoff from the vegetation-free parking lot amounted to 18,521 m3 of stormwater, and in the dry season, it reached 10,949 m3. Introducing pine trees (covering 10% of the area) led to a yearly runoff reduction of 7.3%, while birch trees resulted in a reduction of 4.8%. Both birch and pine trees exhibited greater runoff reduction during the leafed period compared to the leafless period and in wet years compared to dry ones (Mojca Sraj, 2019). In Ohio's urban forest, trees reduced storm runoff by 7%. In Munich, Germany, extending tree coverage by an additional 19% was estimated to reduce runoff by 2%, and highly forested areas near Baltimore were projected to achieve a runoff reduction of 26%. Lei Yaoa, 2015, estimated that adding 11% tree canopy area to the green spaces in central Beijing would enhance runoff retention by 30%. Simulations by (Q. Xiao, 2002) indicated that 29,299 street and park trees in Santa Monica, CA, could annually intercept 1.6% of rainfall, resulting in a decrease in storm water treatment and flood control costs by $110,890.

2.2.7 Tree Characteristics and Species Found in Hawasa city

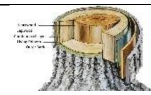
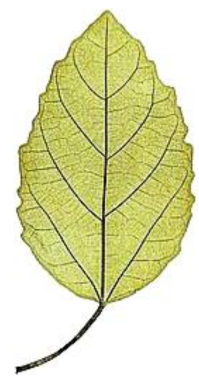
Table 1: Tree Characteristics and Species Found in Hawasa city

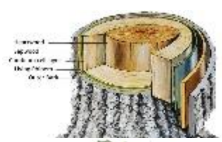
<table>
<tr><th>Tree type</th><th>General Description</th><th>Structure</th></tr>
<tr>
<td>


Ecological and economic benefits of Cordia Africana
C. africana is a **dry-deciduous** tree; it sheds its leaves heavily, usually during the dry season. One very important reason for why it is capable of occurring in drier regions is due to its physiological capacity for minimizing its water consumption and/or loss by either closing its stomata or by drastically shedding its leaves. The shed leaves decompose quite readily, thus ensuring rapid nutrient recycling. As a result of this and other useful biological attributes, the tree can be considered as one of Africa's most important trees (Legesse Negash (2021)).
</td>
<td>
Scientific name: Cordia africana (African cherry)
Local name(s): Wanza
Family: Boraginaceae contains 148 genera and more than 2,700 species
Plant type: Tree and Shrub
Planing month : year round
Origin: Native to Ethiopia
Uses: With its remarkable trait for producing fruits in large numbers from its decorative white flowers, *C. africana* is one of Africa's **multipurpose trees** with a variety of economic, ecosystem, and cultural benefits.
Availablity: available
Suitable altitude up to 3000m.
Average annual temperature 14-31c^{o}.
Average annual rainfall 600-1700mm
Hawasa is located at an elevation of 1738m (5702ft) above sea level.
The tree occurs in primary or secondary forests or woodlands with altitudes ranging from as low as 550 to as high as 2,600 m. The species does well in landscapes with organic matter-rich nitisols or loamy soils, and requires mean annual rainfall of about 1100 mm.

C. africana is dominant in **riparian** habitats and vegetation types. **Riparian vegetation** is a somewhat distinct vegetation system that occurs along banks of permanent or perennial rivers, as well as shorelines of some inland lakes. As Africa's riparian habitats have been under constant 'development' and/or settlement activities, *C. africana* has suffered greatly from these ‘developmental’ and/or deforestation activities. The tree’s replacement with
</td>
<td>
Height: heavily branched tree with a spreading, Umbrella-shaped, or rounded canopy.
It varies in size from a shrub of less than 9 m to a large tree of over 30 m
Spread: trunk up to 1.5–2 m diameter and a broadly conical to rounded or irregular crown.
Plant habit: upright
Plant density: dense
The diameter of the bole may be up to 1 m.
The leaves, with their prominent **abaxial** midribs and veins, are alternate, large and broadly oval, becoming almost rounded, especially in the more mature specimens. Younger and shaded trees typically have longer (over 30 cm) and broader (over 20 cm) leaves, while the more mature specimens possess shorter (up to 18 cm) and narrower (up to 15 cm) leaves.


</td>
</tr>
</table>

	various exotic tree species (including the aggressive eucalypt trees) has also increased the level of threats to this valuable native tree (Legesse Negash (2021)).	
Tree type	General Description	Structure
 **Ecological and economic benefits of Ficus Sur** Ficus sur is a species of tree that can provide numerous environmental benefits. It provides shade and reduces urban heat island effects. It is able to reduce air pollution by trapping air particles in its large leaves thereby preventing them from entering the atmosphere. Ficus sur also helps to conserve energy, since it provides good wind protection, reducing the need for cooling systems. Additionally, it contributes to water conservation due to its efficient use of water and its ability to hold moisture in its large canopy. Finally, this species of tree helps protect biodiversity due to its ability to support a variety of wildlife populations, including birds and insects. Ficus sur has many environmental benefits in a meter cube due to its ability to tolerate high temperatures and droughts, making it an ideal species for reducing evaporation from soils and increasing the water-holding capacity of the soil. It provides habitat to a variety of animal and bird species, helping with pest control in agricultural areas. In addition, Ficus sur can act as windbreaks around areas that are prone to wind erosion and its roots help stabilize the soil on slopes	**Scientific name:** Ficus sur **Local name(s):** Warka **Family:** Moraceae **Plant type:** Tree **Planting month** : year round **Growth Rate**: Fast **Origin:** Native to Ethiopia **Uses:** The figs are edible and utilized in fresh or dried form by native people in many regions. They are also suited to preparation of fig preserve. **Availability:** available Suitable altitude up to 3000m. Average annual temperature 14-31c^{o}. Average mean annual rainfall of ±1000-2000 mm.	Height It usually grows from 5–12 meters (16–39 ft) in height, but may attain a height of 35–40 meters Spread*:* Large specimens develop a massive spreading crown, fluted trunks, and buttress roots. Plant habit: upright Plant density: dense **The diameter of the bole: 2-3m** 

by improving infiltration rates and stopping runoff (Legesse Negash (2021)). .			
 **Ecological and economic benefits of Acacia spp.** The environmental benefit of Acacia spp is that it provides habitat for wildlife, helps reduce soil erosion, and improves air quality. Additionally, Acacia spp can absorb up to 5 1/2 times more carbon than other trees, making them extremely beneficial in the fight against climate change. They also help increase animal biodiversity and provide valuable food sources for various species. Lastly, they can be used as a source of fuel and firewood, helping to reduce deforestation.	**Scientific name Acacia spp.** **Local name(s):** Girar **Family:** Fabaceae **Plant type:** Tree and shrubs **Planting month** : year round **Growth Rate**: Fast **Origin:** Native to Ethiopia, It includes around 1,300 accepted species, native to tropical and subtropical regions throughout the world, with the majority being found in Africa. **Uses:** They often provide important food sources for wildlife and edible timber for humans. The wood from certain Acacia species is valued for its durability and strong structural qualities, making it ideal for use in construction, furniture making, and fuel for cooking and heating. **Availablity:** available Suitable altitude up to 3000m. Average annual temperature 14-31c^{o}. Average annual rainfall 600-1700mm	Height The height of Acacia spp. varies depending on the species and growing conditions. Generally, they range in height from 4 to 15 m Spread*:* The spread trunk of Acacia spp can be up to 15 meters in length. Plant habit: upright Plant density: dense **The diameter of the bole:** The diameter of the bole of Acacia spp vary widely depending on the species and age of the tree, ranging from 0.2m to 1m Leaf: They have compound, bi pinnate leaves with alternate leaflets; petioles are usually swollen at the base.  	

Tree type	General description	structure
	**Scientific name:**Faidherbia albida (Ana tree) **Local name(s):** **Family:** Fabaceae **Plant type:** Tree **Planting month** : year round **Growth Rate**: slow **Origin:** Native to Ethiopia **Uses:** the species are useful in farming for grazing. **Availability:** available Suitable altitude up to 2000m. Average annual temperature 14-31c^{o} Average mean annual rainfall of ±500-1000 mm.	The leaves are typical of the Mimosoideae; compound and bi-pinnate, having leaflets that range from 6-23 pairs Heights of 15 to 20 m. The crown is wide, but may become rounded. DBH (diameter at breast height) of over 1.5 m. The life span of the tree ranges from 70 to 90 years,
	**Scientific name:**/1Combretum collinum (dog-barkcombretum) **Local name(s):** **Family:** Combretaceae **Plant type:** Tree and shrubs **Planting month** : year round **Growth Rate**: is fast growing. trimming and pruning are recommended management strategies. **Origin:** Native to Ethiopia **Uses** is widely used in African traditional medicine in the treatment of various diseases. An infusion or decoction of the roots, stem bark or leaves is taken to treat a large variety of intestinal problems, including abdominal pain, colic, constipation, intestinal worms and further to treat fever, malaria,. bleeding. **Availability:** available Suitable altitude up to 2300m. Average annual temperature 14-31c^{o} Average mean annual rainfall of 800 mm.	Height: shrub or small tree up to 10–16 m tall; crown rounded to flat-rounded; bark black-brown to grey-brown. Leaves opposite, simple and entire; stipules absent; petiole 2–3(–9) mm long

	**Scientific name:** Balanites aegyptiaca (desert date) **Local name(s):** **Family** Zygophyllaceae **Plant type:** Tree **Planting month** : year round **Growth Rate**: slow **Origin:** Native to Ethiopia **Uses:** the species are used for medicine and food **Availability:** available Suitable altitude up to 2300m. Average annual temperature 14-31c^{o} Average mean annual rainfall of ±300-800 mm.	Height: tree reaches 10 m (33 ft) in height with a generally narrow form. The branches have long, straight green spines arranged in spirals. It has a remarkably fluted bole that can be 30cm in diameter, and long, straight, green spines arranged spirally along the branches(useful tropical plant)
	**Scientific name:** Delonix regia (Royal Poinciana) **Local name(s):** **Family** Fabaceae **Plant type:** Tree **Planting month** : year round **Growth Rate**: slow **Origin:** native to Madagascar **Uses:** it is grown as an ornamental tree **Availability:** available Suitable altitude up to 2300m. Average annual temperature 14-31c^{o} Average mean annual rainfall of ±300-800 mm.	**Height:** 10 to 12m **Spread:** 12m to 20 m **Crown uniformity:** symmetrical **Crownshape:** vase,spreading **Crowndensity:** moderate **Growthrate:** fast **Texture:** fine
	**Scientific name Grewia villosa (Velvet tamarind)Local name(s):** **Family** Malvaceae **Plant type:** shrubs **Planting month** : year round **Growth Rate**: fast **Origin:** Eastern Africa **Uses:** used to wash the body as well as to clean the hair and disinfect the scalp **Availability:** available Suitable altitude up to 2300m. Average mean annual rainfall of ±300-800 mm.	usually a deciduous, much-branched shrub growing from 1 - 4 metres tall

	**Scientific name:** Juniperus procera L **Local name(s):** Yehabesha Tid **Family:** Cupressaceae **Plant type:** Tree and Shrub **Planing month :** year round **Origin:** Native to Ethiopia **Uses:** It is an important timber tree, used for building houses, poles, and furniture. The bark is used for beehives. **Availablity**: available Suitable altitude up to 3000m. Average annual temperature 14-31oc. Average annual rainfall 600-1700mm	**Height:** 20–25 m **Spread:** trunk up to 1.5–2 m diameter and a broadly conical to rounded or irregular crown. **Plant habit:** upright **Plant density**: dense
	Scientific name: Calpurnia aure (Ait.) Benth Local name(s): Digta Family: Fabaceae Plant type: Tree and Shrub Planting month : year round Origin: Native to Ethiopia Uses: They make good garden plants because they are easily raised from seed, flower at two years and withstand frost Availablity: available Suitable altitude 1000 m. Average annual temperature 14-31oc. Average annual rainfall 600-1700mm	**Height: 4 to 15 m (2 to 4yr)** **Spread:** trunk up to 0.9–1 m diameter and Irregular orrounded shape **Plant habit:** upright **Plant density:** dense

	Scientific name: Maytenus Local name(s): Atat Family: Celastraceae Plant type: Tree and Shrub Planting month : year round Origin: Native to Ethiopia Uses: It is a medicinal species, being used for treating ulcers and gastrics Availablity: available Suitable altitude 1000 m. Average annual temperature 14-31oc. Average annual rainfall 600-1700mm	**Height: 4 to 10 m** **Spread:** trunk up to 0.9–1 m diameter and Irregular orrounded shape **Plant habit:** upright **Plant density:** dense
	Scientific name: Duranta Common name(s): Duranta Plant type: Tree and shrubs Planting month: year round Origin: Native to Uses: superior hedge; border, For road sides and parks Availability: somewhat available Suitable altitude up to 3000m. Average annual temperature 14-31oc. Average annual rainfall 600-1700mm.	Height: 2m Spread:0 to 1m Plant habit: upright Plant density: dense
	Scientific name: Graviliarobusta Family: Proteaceae Plant type: tree Planting month : year round Origin: Native to Australia Uses: superior hedge; foundation; border,For road sides and parks Availablity: some what available Suitable altitude up to 3000m. Average annual temperature 14-31oc. Average annual rainfall 600-1700mm.	Height: 12- 40m Spread: 2 to 3 m Plant habit: upright Plant density: dense

2.3 Case Study

Singapore has implemented various strategies to cool down its cities, including:

2.3.1 Vegetation:

Vegetation has been used extensively as a UHI mitigation strategy worldwide. Properties of vegetation include high albedo and low heat admittance that have the effect of reducing accumulation of incoming solar energy in the urban area. Additionally, certain types of vegetation such as trees can provide shade and minimise the heat gain from solar radiation, which then improves thermal comfort significantly. Also, the ambient air temperature reduction and building shading by vegetation can lower building energy demand for indoor cooling purpose.

The Vegetation category has been divided into three sub-categories**: Planting Greeneries, Parks and Open Spaces, and Green Corridors.** The first deals with the inclusion of vegetation in the urban design. Most of the strategies can be applied from a retrofitting point of view (e.g. **incorporating green roofs, vegetation around buildings**). Depending on their spatial extension these strategies can address the whole UHI or locally the OTC. The second sub-category, describes the possibilities of managing and improving the thermal performance of open spaces. Finally, the last sub-category focuses on integrating green corridors in the entire city as a way of improving OTC.

2.3.1.1 Planting Greeneries

2.3.1.1.1 Green Roofs

Incorporating green roofs involves placing a vegetative layer such as plants, shrubs, grass or trees on building rooftops. They are also called ‘rooftop gardens’ or ‘eco roofs’. Green roofs can be installed as a thin layer (around 5 cm) of groundcover up to a thick layer (around 1m) of intensive vegetation and trees. The thickness depends on the chosen soil type, drainage system, and vegetation species.

UHI & OTC

Effect this strategy allows for the reduction of the urban heat accumulation due to a lowering of the temperature of roof surfaces. Similarly, nearby air temperature is also influenced by evapotranspiration. It produces benefits in terms of UHI mitigation and the reduction of building energy consumption.

Tropical climate

This strategy has special interest for application in Singapore for two reasons: one, the elevated position of the sun along the year that produces intense vertical radiation over planar surfaces such as roofs and overheating; and two, the high performance and growth of vegetation in humid tropics.

Urban planning Recommendation

Implementation should be aided by the development of building codes and energy efficiency guidelines. Green roofs can be developed both in public and private buildings.

Numerous studies have proven the benefits of green roofs. However, there is still insufficient studies that combine the UHI benefits with the reduction in building energy demand. Different authors have shown that the surface temperature of an individual green roof can be reduced by 15-45ºC compared to conventional or non-green roofs. Additionally, the nearby air temperature can be reduced by 2-5ºC. Reduction of energy consumption can be close to 10 per cent (Refahi and Talkhabi 2015), but could reach 80 per cent depending on the building type (Peng and Jim 2013). Additionally, if extensive use of green roof is undertaken in an urban area, air temperature at pedestrian level could be reduced by 0.5-1.7ºC (Peng and Jim 2013).

2.3.1.1.2 Vertical Greenery

Vertical greenery is defined as the growing of vegetative elements on the external facade of the building envelope. There are two kinds of systems: support system that allows plants to climb through them, and carrier system where plants can settle and develop.

UHI & OTC effect

These systems allow for a reduction of the external surface temperature of the building facades, especially in the case where intense sun radiation occurs, such as on the south facing facades. Consequently, the temperature inside the building can remain more stable and thus there is a reduction in the building energy consumption for cooling. Similarly, there is a reduction of the nearby air temperature providing benefits for pedestrians' thermal comfort. Tropical climate It is an interesting strategy for humid tropics because water access can be provided naturally through atmospheric precipitation (high levels in Singapore) and thus avoiding extra and/or complicated landscaping maintenance.

Urban planning Recommendation

Implementation should be aided by the development of building codes and energy efficiency guidelines. Adequate greenery systems should be selected in accordance to the building structure, the maintenance required, and safety. They could be developed both at public and private buildings at low costs.

The performance of vertical greenery can vary significantly because of the weather conditions that influence plant characteristics or because of the plant species used (Pérez et al. 2014). Studies in Singapore have shown that thicker greenery is key to getting positive results when shading a building and that reductions between 10–31 per cent energy cooling load can be achieved due to the effect of vertical greeneries (Wong et al. 2009).

2.3.1.1.3 Green Facades

Green facades are vegetative layers such as small plants, grass and/or moss attached to external building facades. They are also called 'living walls' and 'vertical gardens'. Green facades can be considered as an alternative to insulating construction materials and reducing indoor overheating.

UHI & OTC effect

The strategy allows for a reduction in the temperature of façades especially those exposed to intense sun radiation, such as the south facing façades. Consequently, the temperature inside the building can remain more stable and thus there is a reduction in the energy consumption required for cooling indoors. Similarly, there is a reduction of the nearby air temperature providing benefits of thermal comfort for pedestrians.

Tropical climate

It is an interesting mitigation strategy for the tropics since reducing direct exposure to sun radiation is a basic requirement in isolating the thermal effect on buildings from the warm exteriors. Its implementation (depending on the case) may not require sophisticated design and maintenance, especially in low-rise buildings.

Urban planning Recommendation

Implementation should be aided by the development of building codes and energy efficiency guidelines. Green walls/façades can be developed both in public and private buildings.

The benefits of green walls or facades have been reported in different studies. Pan and Xiao (2014) reported a reduction of 6.2 per cent in energy consumption, but this could be doubled in tropical climates. During high outdoor temperatures, indoor temperatures can be mitigated between 3-5ºC using this measure, thus improving indoor thermal comfort. Pan and Xiao (2014) also estimated that outdoor temperature close to the façade could be reduced between 0.5-4ºC. The benefits in terms of cooling and thermal isolation, reduction of energy consumption, mitigation of UHI and improvement of thermal comfort can be relevant.

2.3.1.1.4 Vegetation around Buildings

Arranging adequate vegetation elements around buildings can provide shade to pedestrians, building and ground surfaces. The effect can vary depending on the vegetation coverage, size and distribution.

UHI & OTC effect

Vegetation can absorb the incoming solar radiation and thus reduce heat accumulation in urban materials. At the same time, it provides shadowing, especially trees. Similar to green façade, the reduction of solar radiation (shade) in buildings will reduce the energy demand for indoor cooling.

Tropical climate

It is an interesting mitigation measure since reducing direct exposure to sun radiation is one of the most beneficial actions to improve OTC in Singapore.

Urban planning Recommendation

In planning, it is required that urban design considers carefully the exposure of buildings to direct solar radiation. On the whole, urban design needs to look for thermal pleasure by developing an urban asymmetrical thermal environment dominated by cool spots in urban spaces (Emmanuel 2016) and at the same time enabling low-energy cooling within indoors (Kikegawa et al. 2006) that depend on the building structure (Castleton et al. 2010).

Gillner et al. (2015) estimated that tree-shadowed streets could reduce the air temperature between 0.9-2.6ºC. The highest benefit of the shadow provided by trees is improving local thermal comfort during daytime (Shashua-Bar et al. 2012), especially in tropical and subtropical areas.

2.3.1.1.5 Selective Planting

Planting vegetation in selective areas can provide beneficial shade but also obstruct the wind flow. This measure concerns choosing the more effective vegetation species as well as the optimal orientation and arrangement.

UHI & OTC effect

Vegetation allows for the following: a reduction in urban heat accumulation; shadowing that increases pedestrian thermal comfort; and reduction in building energy consumption. Combination of the different types of vegetation species and the way they are arranged can improve the thermal performance of the surrounding considering their ability to influence the urban energy balance.

Tropical climate

This measure is relevant for application in Singapore because of the high growth of vegetation in the humid tropic.

Urban planning Recommendation

Implementation should be aided by the development of building codes and energy efficiency guidelines. New development or retrofit should consider the disposal of vegetation in a way that can provide the highest environmental benefits. The selection of species should factor in their adaptation to the tropical climate in Singapore. In any case, any urban greening programme implemented would need to be appropriately designed to get the most benefit out of reducing temperature (Bowler et al. 2010).

The disposal of vegetation (for example, individual, linear, group, surface plantation) and the species characteristics have significant influence on reducing temperature. Species differ significantly in their ability to reduce air and surface temperatures as well as to increase relative humidity. Trees showing both a high leaf-area density and a high rate of transpiration are more effective in cooling the air temperature. Differences in the surface temperatures of the tree shaded areas are more pronounced compared to the air temperatures of sunlight exposed areas (Gillner et al. 2015). In this sense, a combination of different vegetation elements seems beneficial for outdoor thermal comfort.

2.3.1.1.6 Green Pavements

This measure reduces the amount of artificial material on urban pavements with the replacement of natural soil elements with grass. But it can also be installed by using permeable pavers, pervious concrete or porous asphalt in order to increase the permeability of the pavement.

UHI & OTC effect

Any urban greening programme implemented would need to be appropriately designed to achieve the full benefit of reducing temperature (Bowler et al. 2010). It allows for the reduction of urban heat accumulation by decreasing pavement temperature, thus influencing pedestrians' thermal comfort and to a large extent the UHI.

Tropical climate : This strategy has special interest for application in Singapore because greenery there develops with little maintenance due to the sufficient access to water.

Urban planning Recommendation: Implementation should be focused on areas/pavements with little shadowing (lowrise building development, for example) because the accumulation of heat can rise in pavements under these conditions.

Urban pavements are generally made of materials that can reach peak summertime temperatures of 50 70ºC. The use of grass pavement or other cool materials can reduce the UHI significantly (Flower et al. 2010) because nearly 30-45 per cent of urban areas is covered by pavements.

2.3.1.1.7 Infrastructure Greenery

This measure covers elements that are not part of natural growing vegetation. Greenery can be added on existing infrastructure such as bridges, tunnels, highways and bus stations.

UHI & OTC effect

It allows for the reduction of the urban heat accumulation by decreasing surface temperature, and thus influencing pedestrians' thermal comfort. Tropical climate Although design with greenery is generally considered to be a good strategy, shadowing green elements would be even more beneficial to improve outdoor thermal comfort.

Urban planning Recommendation

Implementation should be focused on areas/pavements with little shadowing (low rise building developments) because the accumulation of heat can rise in pavements with these conditions. Additionally, the development of small green urban areas that are located strategically or grouped around buildings should be encouraged. These are more easily implemented when retrofitting in comparison with the development of big urban parks inside urban areas (Wong and Chen 2009).

Greenery does not only have positive effects on thermal comfort (Tallis et al. 2015), it also removes air pollutants and gives positive psychological effects. In this sense, during heat stress periods, Lafortezza et al. (2009) found that urban vegetation provided people the perception of well-being.

2.3.1.1.8 Macroscale Urban Greening

Macro scale urban greening concerns the large-scale increase of the presence of vegetation in urban areas focusing on big urban parks, forests and natural reservoirs. They can be located at the edge or in central areas of the city with different effects in the local climate. They are also called 'cold islands'.

UHI & OTC effect

Areas like forests and green belts do not only assure a better thermal perception inside them, but can also provide coolness to nearby urban areas, thus helping to regulate the accumulation of heat in the whole urban area.

Tropical climate

This measure could be more of interest in dry tropical climates where the effects of reduced heat accumulation and the provision of fresh air into the city can always help improve OTC and reduce UHI. In this sense, in humid tropical areas, this measure can be considered low cost, considering the potential growth of vegetation and the low irrigation needs for maintenance as compared to those in non-humid areas.

Urban planning Recommendation

Implementation of macroscale urban greening should be considered carefully and in relation to general climate patterns (such as wind pattern) to maximise the cooling benefits that could extend to the entire urban area. The collaboration among several ministries is crucial for the successful implementation of urban greening on a large scale.

The cooling effect of vegetation on the urban surface temperature and air temperature is mainly determined by the species group, canopy cover, size and shapes of the parks (Feyisa et al. 2014). An experimental study by Lin and Lin (2010) also indicated that the cooling efficiency of urban parks is mostly influenced by leaf colour and foliage density. In any case, the generalisation of the cooling effects of big parks is difficult since it depends on the biophysical characteristics of vegetation in relation to the regional climate. However, the benefits of big urban green areas have been determined (Rosenzweig et al., 2006), the temperature difference between urban, and park areas has been found to be from 1.5-4 º C (Jonsson, 2004).

2.3.1.1.9 Transport Corridors

The vegetation arrangement along transport corridors can provide shade to the infrastructure surface. The effect can vary depending on the vegetation density, height and species. But it is also key to combine the reduction on incoming solar radiation with the natural ventilation capacity of these spaces.

UHI & OTC effect

Vegetation can absorb incoming solar radiation and thus reduce heat accumulation in urban materials. At the same time, it provides shadowing (in the case of trees). Thus, considering local pedestrian OTC, an increase in the number of trees makes sense. However, transport corridors are often open spaces that can be used as ventilation paths to introduce fresh air into the urban area and/or help remove the accumulation of heat. Thus, these transport corridors should be carefully designed with respect to UHI and OTC.

Tropical climate : Adequate use of transport corridors can be useful in reducing the heat trapped in the urban surfaces in the whole urbanised area of Singapore.

Urban planning Recommendation: In planning for arranging vegetation along transport corridors, the exposure to direct solar radiation and wind enhancement should be considered carefully. A combination of different heights of vegetation elements together with their strategic location can allow for suitable airflow inside the transport corridor and thus pose higher benefits for this mitigation measure. These planted trees along ventilation areas should not form dense windbreaks.

It is important to be aware that good ventilation leads to positive effects in terms of temperature and air quality (Ng and Ren 2015). Additionally, cooler surfaces with low roughness such as grass may allow air to move gently along corridors, thus avoiding turbulent vertical air movements produced by hot surfaces.

2.3.1.1.10 Mean Building/Tree Height

The relation between building and tree height will condition the amount of façade that is shaded by the trees and thus control the overheating of its surface.

UHI & OTC effect

Trees reduce direct solar insolation thereby decreasing the surface temperature, both of building façades and in the tree surroundings. This way a reduction in UHI and an increase in local thermal comfort is expected together with benefits of indoor cooling energy demand.

Tropical climate

The combination of greenery shade in relation to building geometry is considered to provide the best benefits in tropical areas because the regional air temperature and levels of humidity are already high next to the thermal discomfort levels.

Urban planning Recommendation

Implementation should be aided by the development of building codes and energy efficiency guidelines. Adequate tree heights should be implemented in each area and other issues such as natural lighting should be considered.

Trees are considered suitable passive elements that help improve not only outdoor thermal comfort but also indoors. The average transmissivity of direct solar radiation through the foliated and defoliated tree crowns was estimated to range from 1.3 to 5.3 per cent and from 40.2 to 51.9 per cent respectively (Konarska et al. 2014). In his study based on measurements, Morakinyo et al. (2013) found that in comparison with a shaded building, an unshaded building had higher indoor air temperatures and these remained as such for a longer time. Indoor–outdoor temperature differences showed a peak of 5.4 °C for the unshaded building while the tree-shaded building did not exceed 2.4 °C.

CHAPTER THREE MATERIAL AND METHOD

3 Study Area Description

Hawasa is located in the Sidama Region of Ethiopia. Geographic coordinates of latitude, North 7º 3’ 0″ and 6′ 45″, and longitude, East, 38º 28′ 0’’, at an elevation of 1,775 meters (5,823 feet) and lies 333 kilometers (207 mi) to the south-west of Addis Ababa. Hawassa is administratively segmented into 8 sub-cities and 32 Kebeles, encompassing a total administrative land area of 15,720 hectares within its municipal boundary

Hawasa city is located on the shores of Lake Hawassa in the Great Rift Valley. Lake Awassa is about 15 km long and 5.5 wide, with a maximum and mean depth of 21 m and 10 m, respectively, situated at the centre of a collapsed large caldera, at an altitude of 1680 m above mean sea level (m a.s.l.) (NUPI 1994). The catchment of Lake Hawassa is formed of Pliocene-age volcanic rock. Significant faults and ground cracks in the rock result in a highly permeable soil and unconfined aquifers in the area. The distance to the static groundwater level fluctuates, ranging from a shallow depth of a few meters in low-lying regions to as deep as 40 meters in elevated areas (Ayenew and Tilahun, 2008)

Climate of Hawasa has a mean annual rainfall of about 950 mm and temperature of 20°C. Typically, the primary rainy season periods start from June to October.

The Ethiopian Central Statistical Agency estimates that the population of Hawasa is 351,469 and it has an annual population growth rate of 4% (CSA, 2015). The population is relatively young, with 65% under 25 years of age and around 5.5% over 50 years of age.

.

3.1.1 Location Map

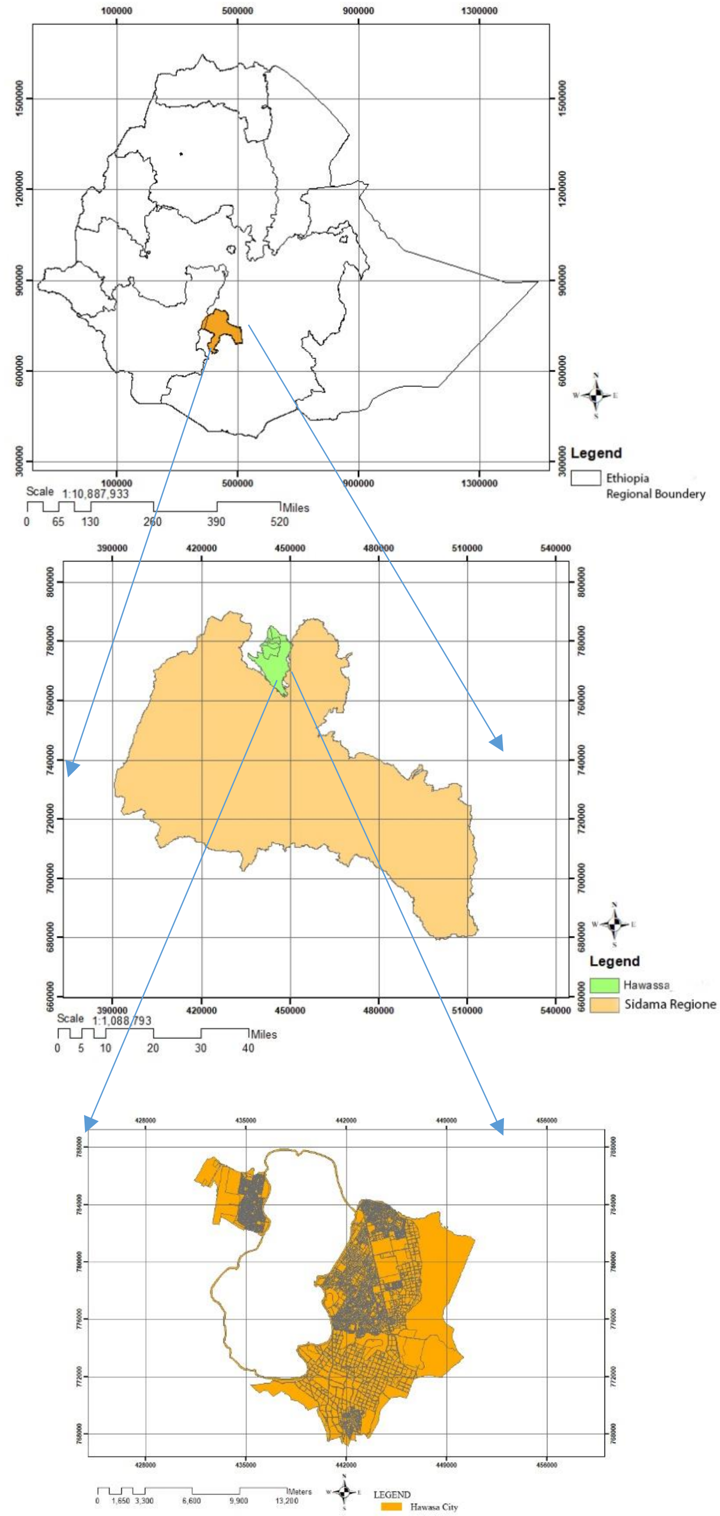


Figure 2: Locational Map of Hawasa City Administration (2007 E.C)

3.1 Research design

Research design refers to the overall plan or structure of a research study that outlines how data will be collected, analyzed, and interpreted to address the research questions or hypotheses. It's like a blueprint that guides the entire research process from start to finish. A well-designed research study is crucial for ensuring valid and reliable results. Key components of this research is presented in figure-1 below.

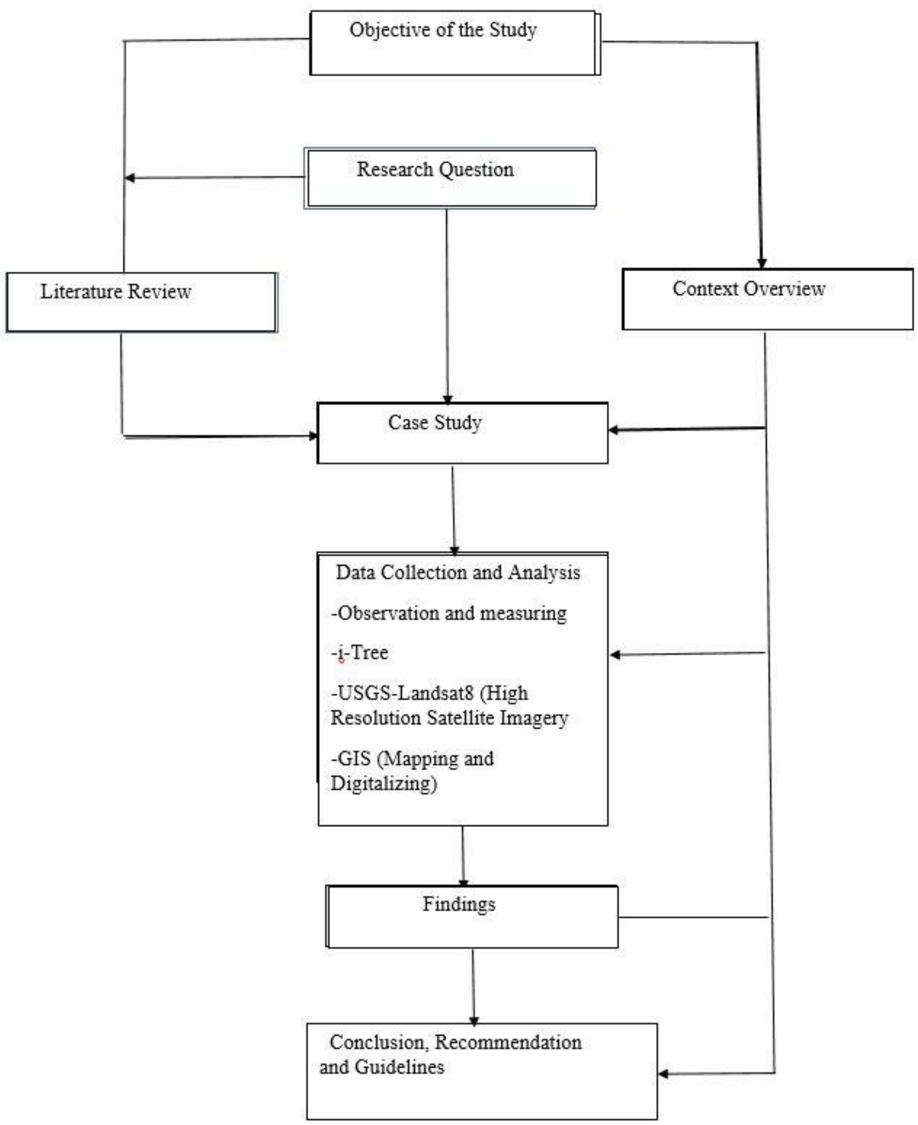


Figure 3: Research Structure

3.1.1 Method of Data Collection

Type and Data source

The data used for the research was based on the Land use map of the Hawasa city provided by Hawasa city Administration. Based on the land use map ground measurement and observation was made to identify the trees in deferent part of the city by preparing Base Map. The following steps was made to collect data from the ground':

1. High-resolution satellite imagery or aerial photographs of Hawasa city(USGS/Landsat8,2023).

2. Land Use map of Hawasa city of year 2007E.C.

3. Ground truth data, collected through field surveys and site visits, were used for validation and accuracy assessment of the remote sensing analysis.

3.1.1.1 Land Use Land Cover of Hawasa City

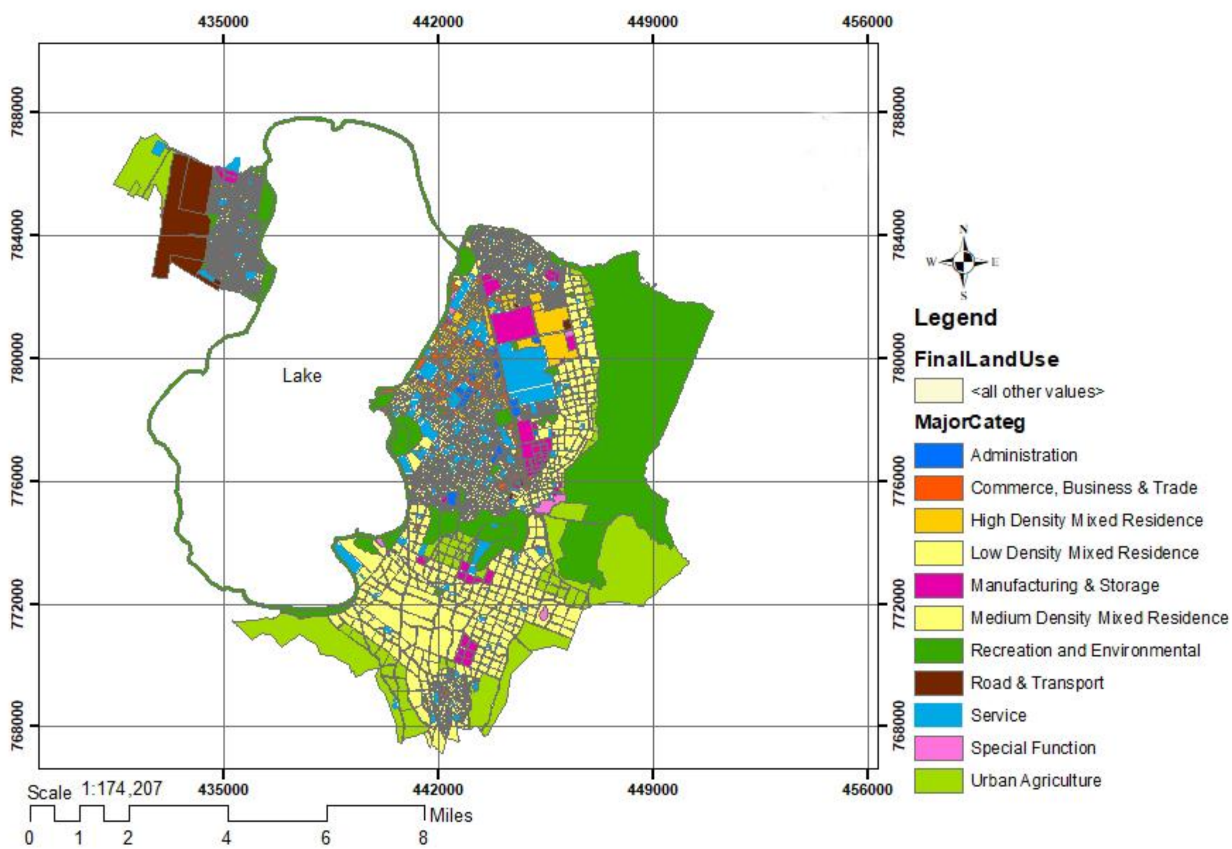


Figure 4: Land Use Map of Hawasa City (Source Hawasa City Administration, 2007 E.C)

The land use and land cover of Hawasa city is characterized by a combination of built up area, agricultural, and natural land cover types. According to a study published in the Urban Planning and Transport Research in 2023, the land cover of Hawasa city can be classified into the following categories:

- ✓ Built-up areas: include residential, commercial, and industrial areas, as well as roads, parking lots, and as well as other infrastructure.
- ✓ Vegetation: it includes natural vegetation such as forests, woodlands, and grasslands, as well as agricultural crops and plantations.
- ✓ Water bodies: include lakes, rivers, and other bodies of water.
- ✓ Bare soil: includes areas with little or no vegetation cover, such as bare ground, rock outcrops, and quarries.
- ✓ Agriculture land
- ✓ According to the research, the main land cover type in Hawasa city is Agriculture land, which cover around 28.76% of the total area. Built-up areas 16.85%. Vegetation covers including shrubs and grass around 16.88% of the area, while water bodies cover around 35.03%. Bare soil covers the remaining 2.48 % (Woldegebriel et al. 2023).

3.1.2 Data Analiysis:

The analysis of tree canopy cover in Hawasa city was conducted using the i-Tree canopy software and USGS-Landsa8. A component of the i-Tree tool developed by the United States Forest Service in 2006. This web-based tool, available for free access, generates quantified and statistically valid values for canopy cover.

The sampling procedure followed four major steps:

1. defining of the study area boundary by importing boundary shapefile of the Hawassa city into the i-Tree canopy,
2. predefinition of the land surface cover types to be surveyed
3. Classification of each random point overlapped on the aerial image that shows the land surface cover types categorized as Tree, impervious surface shrub and bare land. The defined area for this study includes the urbanized part of the Hawasa city

4. The land surface cover of the study area was quantified using a random point sampling procedure. Sample points were randomly distributed by the i-Tree software onto the 2023 Google Map image, and the materials that covered the ground were classified by interpreting the coverage types within the Hawasa city
   A total of 503 random sample points were repeatedly added and classified

i-Tree Landscape

Another way to measure tree canopy is through the i-Tree Landscape tool. This tool uses land cover data from the National Land Cover Database. Once a location is selected, an estimate of the amount of tree canopy is provided. You can also explore location data (census data, forest risk, future climate, etc.), see tree benefits, prioritize tree plantings, and generate reports. This is a great, free tool from i-Tree with lots of information to explore.

Point Sampling

The simplest method is to use a point sampling technique developed by the i-Tree Canopy tool. Random points, like those shown in the map, are generated within an area and manually assigned a value of “tree” or “non-tree” until a 1-2% standard error is reached. By dividing the number of "tree" points by the total number of points, you can quickly get an estimate of the percent canopy cover or any other land cover type.

High Resolution Land Cover Mapping(landsat8)

The third method uses (GIS) remote sensing technology and high-resolution imagery (aerial or satellite). These data inform all other aspects of the project by categorizing a given landscape into specific classes such as tree canopy, other non-canopy vegetation, impervious or hardscape, bare soil, or water. With this information in hand, you can then look at the quantity and geographic distribution of each type of land cover and ask many questions like:

- Where is there existing tree canopy? How much?
- How much gray infrastructure (roads, buildings, parking lots, etc.) is there compared to green infrastructure (trees, grass, and other vegetation)?
- Where are potential planting opportunities to increase canopy coverage and address specific issues?

3.1.3 Carbon in Tree

To calculate carbon in each tree which found in the city depending on their respective species needs certain steps as follow:

Calculate the height: of each tree, noting that Θ_1 is the angle to the top of the tree and Θ_2 is the angle to the base of the tree. The tangent of the angle is expressed as tan. The distance between you and the tree is expressed as AB.

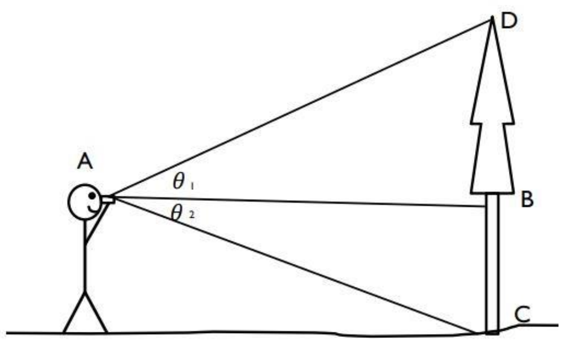


Figure 5: Tree Height Diagram

$\tan \Theta_1$=DB/AB/1DB = AB $\tan\Theta_1$

$\tan\Theta_2$=BC/AB/1BC = AB $\tan\Theta_2$

Total tree height = DB + BC = AB (tanϴ1 + tanϴ2)……………….Equation 1

Calculating Carbon Storage (adapted from Trees for the Future, 2007**)**

3.1.3.1 Calculating Green Weight (GW)

Green weight is the amount of biomass (or mass of living tree material) per unit of area, and is generally expressed as kilograms per hectare (kg/ha). It refers to the total amount of aboveground parts of a tree, including foliage, twigs, branches, bark, and stems.

Calculate the aboveground green weight of a tree based on the tree's diameter and height. To find the green weight, insert the values you obtained for diameter (cm) and height (m) into the appropriate equation.

GW = r^2 x h/1……………………………………equation 2

Calculating Dry Weight (DW)

Dry weight represents the mass of the wood in the tree when dried in an oven so the moisture is removed. On average, experiments have shown that a tree's dry weight is about 50% of its green weight. Therefore, to find the dry weight, you just need to multiply green weight (GW) by 50%.

DW = GW X 0.5/1………………………………. equation 3

3.1.3.2 Calculating Carbon Storage (C)

Carbon storage is the amount of carbon that is within the wood of the tree. This is the total amount of carbon that is captured from the atmosphere during photosynthesis as well as the amount of carbon sequestered by the tree. From experiments, scientists have found that about 50% of a tree's dry weight is carbon. To find carbon storage, multiply dry weight (DW) by 50%.

C = DW X 0.5/1……………………………………equation 4

3.1.4 Rainfall Interception by Trees

The volume of water that intercepted by tree during rain is calculated as follow:

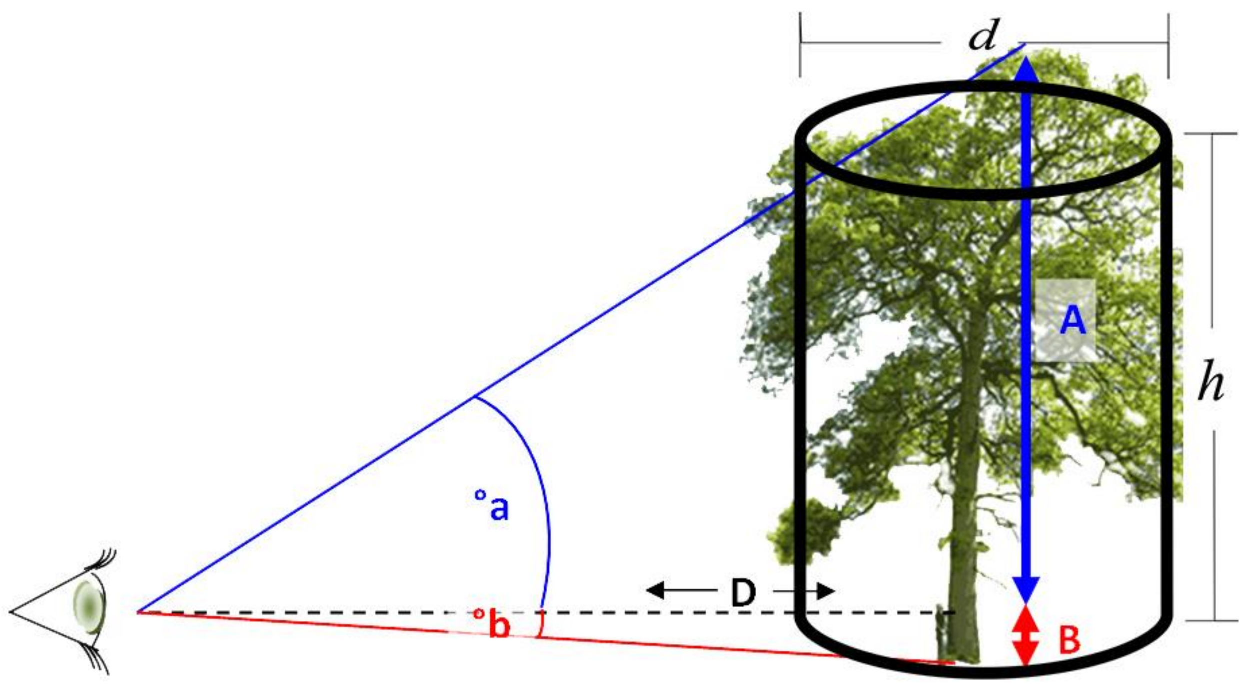


Figure 6: Rainfall interception Diagram

RF = $\pi r^2 h$……………………………………………………………………equation 6

3.1.5 Albedo of the Tree

To calculate the amount of solar radiation reflected from a tree, you can use the following formula:

Reflected solar radiation = (albedo of the tree) x (solar radiation at the tree)

The albedo of the tree is the fraction of solar radiation that is reflected back by the tree. The albedo of a tree can variety on the species of the tree, the age of the tree, and the density of the leaves.
To calculate the solar radiation on the tree, we can use the following formula

Solar radiation at the tree = (sun regular) x (cosine of the solar zenith thoughts-set)

The sun steady is the amount of solar radiation that reaches the top of the earth's environment, this is about 1361 watts constant with rectangular meter. The solar zenith mind-set is the attitude some of the sun and the vertical axis of the observer.

The albedo of a tree can be calculated through way of measuring the quantity of daytime that is reflected through the tree's leaves and evaluating it to the amount of daytime this is absorbed. Right here are the stairs to calculate the albedo of a tree:

1. Measure the amount of incoming sunlight: Use a pyrometer or other device to measure the amount of sunlight that is shining on the tree.
2. Measure the amount of reflected sunlight: Use a pyrometer or other device to measure the amount of sunlight that is reflected by the tree's leaves.
3. Calculate the albedo: Divide the amount of reflected sunlight by the amount of incoming sunlight to get the albedo. For example, if the tree reflects 30% of the incoming sunlight and absorbs 70%, the albedo would be 0.3.

It is important to note that the albedo of a tree can vary depending on several factors such as the color and texture of the leaves, the density of the canopy, and the amount of sunlight that is reflected or absorbed by the tree. Additionally, the albedo of a tree can also be influenced by other factors such as the age and health of the tree, the location and climate of the area where it is growing, and the time of day or year.

CHAPTER FOUR RESULT

4 Hawasa City Canopy Assessment

According to the Hawasa city tree canopy analysis, the study found that the total percentage of the tree canopy cover is 18.09%. the study was done compering the tree canopy cover with other land cover (Table2), such as impervious surface (built up landscape)35.39%,Grass/Herbaceous 11.73%,Shrubs 8.35%, Bare Ground 6.36% and Water 20.08% of the Hawasa city. This data give consideration for the balanced distribution of the existing land cover. For example, the Bare ground which account 6.36% cover 9.99 Sq.Km area of the Hawasa city give additional room for future planting of additional trees in situation there is need for planting the tree to meet the desire goal by Hawasa city Administration.

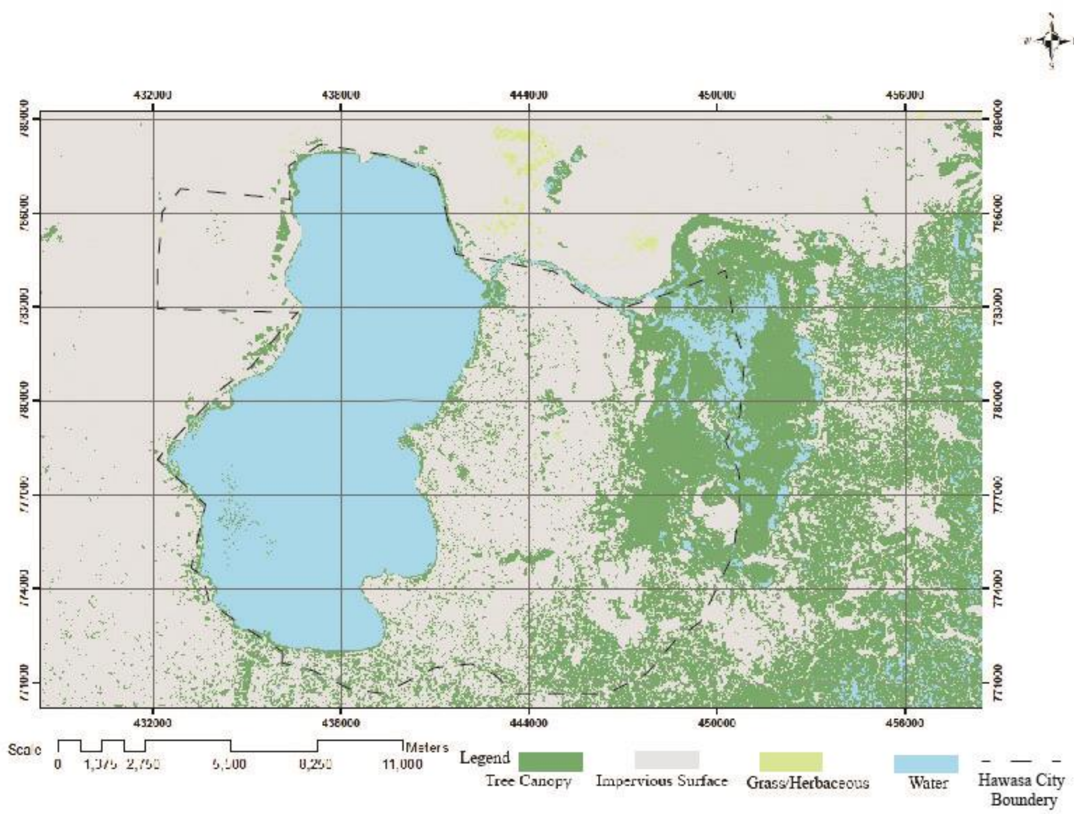


Figure 7: Tree Canopy Cover Assessment Map of Hawasa city

The result in table 3-5 present the existing 18.09% of tree Canopy cover benefit in reduction capacity towards the air pollution, mitigate runoff water and avoid additional energy usage for indoor cooling purposes. The result shows existing 18.09% of tree canopy cover in Hawasa city have extensive benefit in reducing 21.64KT (Table-3) of Carbon Dioxed from Hawasa city surrounding air and avoid runoff water of 35.82 Kgal (Table-5).

The result in (Table-6page60) Studied the individual tree benefit depend on their reduction capacity towards Air Pollution, Runoff and Urban Heat Island. After studied the reduction capacity of each tree species listed in (Table-6page60), then using the result to determine the number of tree needed to reduce air pollution emitted in Hawasa city and determine the number of tree species needed to mitigate runoff and Urban Heat Island.

Land Cover class of Hawasa City

Abbr.	**Cover Class**	**Ground Points**	**% Cover ± SE**	**Area (mi²) ± SE**
H	Grass/Herbaceous	59	11.73 ± 1.43	4.00 ± 0.37
IO	Impervious Other	0	0.00 ± 0.00	0.00 ± 0.00
IS	Impervious Surface	178	35.39 ± 2.13	10.04 ± 0.54
S	Shrubs	42	8.35 ± 1.23	5.13 ± 0.32
S	Soil/Bare Ground	32	6.36 ± 1.09	3.63 ± 0.28
T	Tree Canopy	91	18.09 ± 1.72	9.62 ± 0.44
W	Water	101	20.08 ± 1.79	5.13 ± 0.46
Total		**503**	**100**	37.55

Table 2: Land Cover class of Hawasa City (Source: Data analyzed Using iTree)

The study analyzed total area of the Hawasa city which 157.2 Sq.Km . From the total area analyzed 24.90 Sq.Km area is covered by Tree canopy this account for 18.09% of the total Canopy coverage of the Hawasa city.

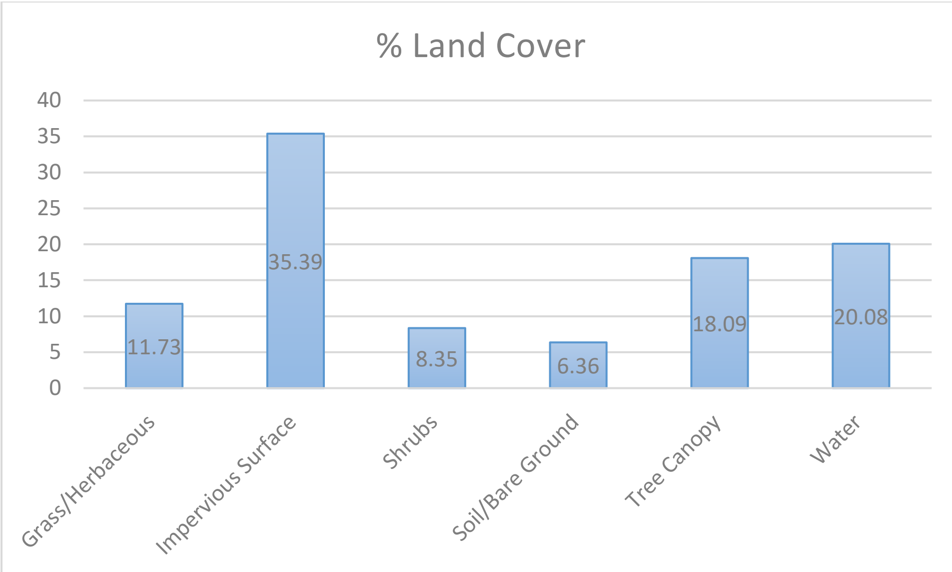


Figure 8: Tree Canopy and Land Cover Data Summery of Hawasa city

4.1.1 Tree Benefits Estimate: Carbon

Tree Benefits Estimate to reduce Carbon in Air for Hawasa city

Description	Carbon (kT)	±SE	CO_2 Equiv. (kT)	±SE 2	Value (USD)	±SE
Sequestered annually in trees	5.9	±0.44	21.64	±1.61	$1,006,695	±74,867
Stored in trees (Note: this benefit is not an annual rate)	148.24	±11.02	543.53	±40.42	$25,281,893	±1,880,185

Table 3: Tree Benefits Estimate to reduce Carbon in Air for Hawasa city (Source: Data analyzed Using iTree).

According to the study result in the Table 3 above represent 5.9KT/mil^2/yr of carbon sequestration, represents the estimated amount of carbon dioxide (CO2) sequestered by 18.09% (Table2) of tree canopy found in Hawasa city, measured in metric tons. This figure is part of the estimated tree benefit, specifically related to the ecosystem service of carbon sequestration. This number represents 5.9 kilotons, where 1 kiloton is equal to 1,000 metric tons. Therefore, 5.9KT is equivalent to 5,900 metric tons.

In this Study, the estimated benefit of trees is specifically related to the positive environmental impact they have through the sequestration of carbon. Urban forestry tools like i-Tree use models and data to estimate the amount of carbon sequestered by trees based on factors such as tree species, size, density and other relevant parameters. As a result, the figure 5.9KT/mil^2/yr of carbon sequestration for the estimated tree benefit recommends that in the given context or area of Hawasa city, urban trees with 18.09%(Table2) of canopy cove are estimated to sequester approximately 5,900 metric tons of carbon dioxide per a Sq.mile per year, providing a substantial environmental benefit by contributing to climate change mitigation efforts. This information is valuable for understanding and quantifying the role of urban trees in reducing greenhouse gas emissions and enhancing overall environmental quality.

The Estimated benefits for the total canopy coverage of the Hawasa city to sequester carbon is 5.9 KT of carbon (Table3), this could exchange in USD currency it will be $1,006,695(Table3).

4.1.2 Tree Benefit Estimates: Air Pollution

Tree Benefit Estimates to reduce Air Pollution for Hawasa City

Abbr.	Description	Amount (T/mil^2/year)	±SE	Value (USD)	±SE
CO	Carbon Monoxide removed annually	2.44	±0.18	$3,257	±242
NO2	Nitrogen Dioxide removed annually	13.49	±1.00	$5,896	±438
O3	Groundlevel Ozone removed annually	104.24	±7.75	$270,791	±20,138

SO2	Sulfur Dioxide removed annually	6.63	±0.49	$888	±66
PM2.5	Particulate Matter less than 2.5 microns removed annua	5.33	±0.40	$566,903	±42,160
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annua	29.58	±2.20	$185,449	±13,792
Total		**161.72±12.03**		**$1,033,185**	

Table 4: Tree Benefit Estimates to reduce Air Pollution for Hawasa City (Source: Data analyzed Using iTree).

The result found using i-Tree, estimates of the air pollution reduction benefits associated with tree canopy cover of Hawasa city 18.09%(Table2) as showing in Table-4 above. The specific benefits can include the removal of various pollutants, such as carbon monoxide (CO), particulate matter (PM), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone, among others. The tool quantifies these benefits based on factors like tree Leaf density, species, size, and location. Here are some key results regarding the estimated air pollution benefits of tree canopy of Hawasa City studied Using iTree.

Particulate matter (PM) Removal: The estimate reduction in PM concentrations achieved by the tree canopy of Hawasa City which cover 18.09%(Table2) of the total area of the city is 5.33T/mil^2/year(Table4). Hawasa city Trees canopy capture, filter out particulate matter, contributing to improved air quality and reduce the cost of Heating and cooling in door by $566,903(Table4).

Ozone Reduction: the result of the study consider the indirect benefits of trees in reducing ground-level ozone concentrations through the release of volatile organic compounds (VOCs). On the ground level, ozone can also be found as a component of smog. Ground-level ozone is a secondary pollutant, meaning it is not directly emitted into the air but forms through complex chemical reactions involving precursor pollutants like nitrogen oxides and volatile organic compounds in the presence of sunlight. The total Ozone reduction by tree canopy cover of 18.09% (in Table2) of Hawasa city is 104.24T/mil2/year(inTable4)and save the cost of human Health and energy for Heating and Cooling indoor by $270,791. While ozone in the stratosphere is beneficial, ground-level ozone can have adverse effects on human health, causing respiratory problems and other health issues.

The total estimated benefit of the existing tree canopy cover of Hawasa city in reducing Air pollution is 161.72T/mil2/year (Table4) with reduction cost for human health and energy cost for heating and cooling indoor of $1,033,185. One of the result this study found is the research gap between the canopy cover of Hawasa city and human health.

4.1.3 Tree Benefit Estimates: Hydrological

Tree Hydrological Benefit Estimates for Hawasa city

Benefit	Amount (Kgal)	±SE	Value (USD)	±SE
Avoided Runoff	35.82	±2.66	$320	±24
Evaporation	804.35	±59.82	N/A	N/A
Interception	809.58	±60.21	N/A	N/A
Transpiration	761.65	±56.64	N/A	N/A
Potential Evaporation	5,172.93	±384.70	N/A	N/A
Potential Evapotranspiration	4,266.33	±317.28	N/A	N/A

Table 5: Tree Hydrological Benefit Estimates for Hawasa city (Source:Data analyzed Using iTree).

Trees play a vital role in the urban hydrological cycle. They can intercept rainfall, reduce storm water runoff, and contribute to groundwater recharge. The figure in Table5 indicates the capacity of the existing tree canopy cover of Hawasa city to intercept 809.58 gall/mil^2/yr and avoide runoff by 35.82kgall/mil^2/year, helping to mitigate the impact of storm water runoff on urban areas.

It is important to note that the benefits can vary based on factors such as tree species, canopy density, soil type, and local climate conditions. The i-Tree tools use scientific models and data to provide these estimates and help urban planners make informed decisions about managing and preserving urban forests for their ecological and societal benefits.

According to the analysis in Table2, we have 18.09% of canopy cover in Hawasa city, it can provide several benefits for carbon sequestration and reducing storm water, including: Carbon storage of 543.53 KT from Table3: Trees absorb carbon dioxide from the atmosphere and store it in their biomass and in the soil. Having a high percentage of canopy cover in an urban area can increase the amount of carbon stored, helping to mitigate the effects of climate change and save energy cost of $25,281,893.

Carbon dioxide (CO_2) sequestration of 21.63KT in Table3: Trees also sequester carbon by converting it into organic matter through photosynthesis by removing 2.44Tone of carbon monoxide annual per mile squere(Table4). This process helps to remove carbon dioxide from the atmosphere, store it in the tree’s biomass, and save as energy cost of $1,006,695(Table3).

Improved air quality: Trees absorb pollutants such as carbon dioxide, nitrogen dioxide, and particulate matter, improving air quality in urban areas. This can help to reduce the amount of carbon emissions from transportation and other sources, According to Table4 Total of 161.73Tone emission utilized by 18.09% of canopy cover in Hawasa city end up saving $1,033,185.

Reduced storm water runoff of 135,590 liter from Table5**:** Trees help to absorb and filter rainwater, reducing the amount of storm water runoff and the risk of flooding. This can help to protect the city's infrastructure and reduce the risk of property damage and saving $320 in Kgal/mi^2/yr. The estimated benefits of the existing tree canopy coverage of Hawasa city avoid runoff of 35.82 Kgal/mi^2/yr (in Table5).

Overall, having 18.09(Table2) percent of canopy cover in Hawasa city, Ethiopia can provide significant benefits for carbon sequestration and storage, helping to mitigate the effects of climate change and improve the overall health and well-being of the city's residents.

4.2 The tree species found in Hawassa city, Ethiopia

1. *Cordia africana (African cherry)*
2. *Ficus sycomorus*
3. *Grewia villosa (Velvet tamarind)*
4. *Acacie abyssinica*
5. *Duranta*
6. *Juniperus procera*
7. *Calpurnia spp*
8. *Grevillea robusta*
9. *Maytenus*
10. *Cordia*
11. *Dombeya torrida*
12. *Faidherbia albida (Ana tree)*
13. *Combretum collinum (dog-bark combretum)*
14. *Balanites aegyptiaca (desert date)*
15. *Delonix regia (Royal Poinciana)*

4.3 Street Tree and Characteristics

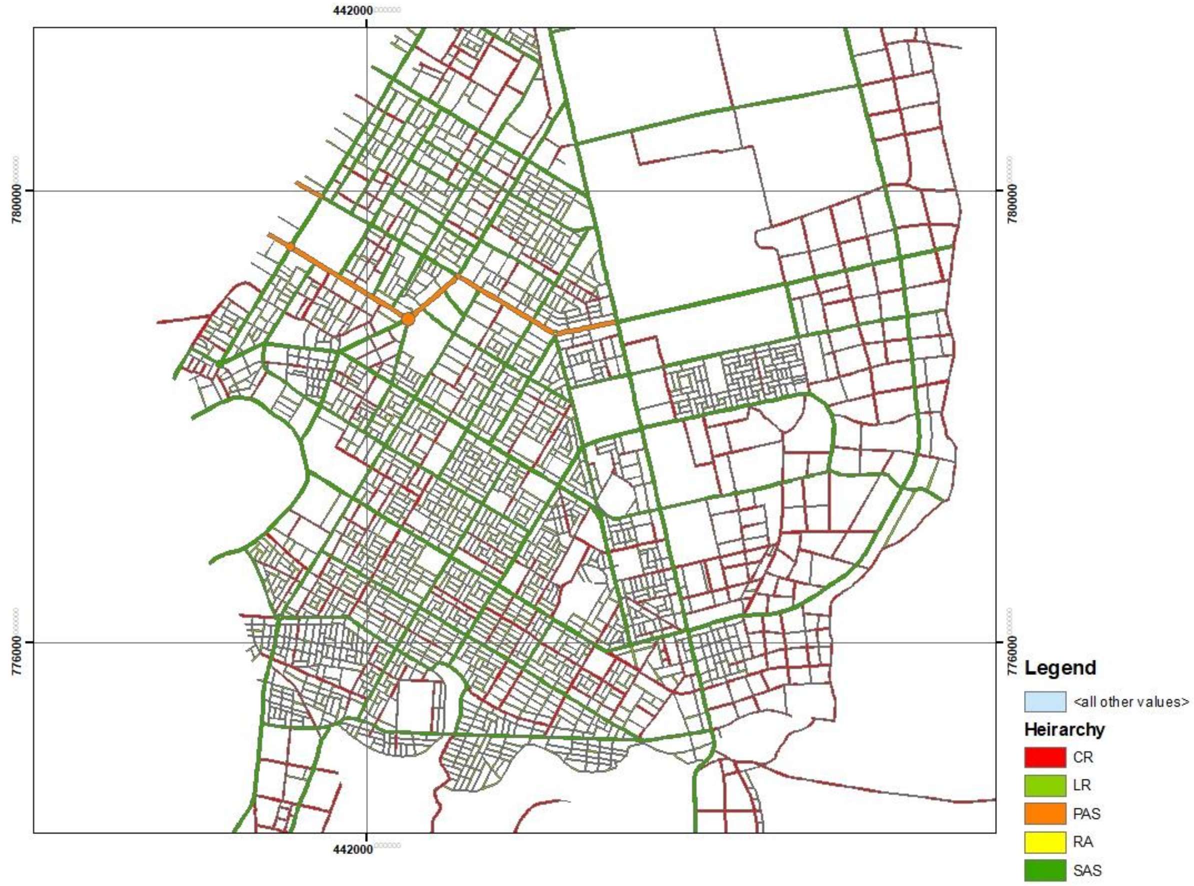


Figure 9: Hawasa city street Network; source Hawasa city Administration

Regarding street tree species found in Hawassa city, Albizia lebbeck, Grevillea robusta, and Jacaranda mimosifolia were dominant species. The diameter distribution at breast height of Albizia lebbeck, Grevillea robusta, and Jacaranda mimosifolia ranged from 10 cm to 20 cm, with canopy covers varying between 20% to 70% with respect to the area it accupaide. Another tree species found on the street of Hawasa city is Cordia africana, a common street tree in Hawassa city. The diameter distribution and canopy cover of Cordia africana depended on the spacing of the trees on the roadsides. The diameter distribution and canopy covers of street tree species differ based on various factors such as location, climatic conditions, and soil type. In Hawassa city, Albizia lebbeck, Grevillea robusta, and Jacaranda mimosifolia are the dominant species, and their diameter distribution and canopy covers are between 20% to 70%, (source ground surveying).

4.4 Estimate The reduction Strategy for Carbon Dioxide, Air Pollution and Storm water Impacts.

4.4.1 Tree Benefits (Benefits are based on USDA Forest Service research)

In the Table 6 below twelve-tree sample were taken for the evaluation of their benefits in cleaning the environmental air, storm water mitigation and reducing energy emission. Their serving size of each individual tree were determine within diameter of 1m to 12m of their canopy cover with total land area coverage of 241m^2 and their carbon equivalent were 259,957.78kg.

The benefit of those twelve tree sample annually were $13,430.5 US dollar this benefit is not only for carbon equivalent but also for runoff water mitigation and avoid usage of other energy sources for cooling or heating purpose

Particles	Acacia: Acacia spp, (Acacia), Serving Size: 3x12m. diameter Condition: Excellent Estimated this year: $4.34	Ficus Sur: F (Ficus ampelas) Serving Size: 12x12m. diameter Condition: Excellent Estimated this year: $8.44 Annual value	African juniper, (Juniperus procera) Serving Size: 4x4m. diameter Condition: Excellent Estimated this year:- $17.96 Annual value	Calpurnia: Calpurnia spp, (Calpurnia) Serving Size: 2x2m. diameter Condition: Excellent Estimated this year: $7.32 Annual Value	Maytenus: Maytenus obtusifolia Serving Size: 1x1m. diameter Condition: Excellent Estimated this year: $30.10 Annual Value	Duranta Serving Size: 1x1m. diameter Condition: Excellent Estimated this year: $34.93 Annual Value	Grevillea robusta: Silk oak, (Grevillea robusta) Serving Size: 3x3 cm. diameter Condition: Excellent Estimated this year: $48.89 Annual Value	Eucalyptus globulus: Blue gum eucalyptus, (Eucalyptus globulus) Serving Size: 5x5m. diameter Condition: Excellent Estimated this year: $65.59 Annual Value	Cordia: Large leaf cordia, (Cordia africana) Serving Size: 5x5 cm. diameter Condition: Excellent Estimated this year: $46.24 Annual Value	Grewia villosa : Grewia spp, (Grewia) Serving Size: 4x4m. diameter Condition: Excellent Estimated this year: $45.98 Annual Value	Dombeya torrida : Cape Wedding Bells, (Dombeya tiliacea) Serving Size: 4x4m. diameter Condition: Excellent Estimated this year: $47.18 Annual Value	Hyphaene compressa: Hyphaene spp, (Hyphaene) Serving Size: 2x2m. diameter Condition: Excellent Estimated this year: $68.72 Annual Value
Carbon Dioxide Uptake	$0.14	$0.14	$4.81	$0.14	$0.26	$0.35	$0.18	$0.18	$0.18	$0.54	$0.18	$0.14
Carbon Sequestered	0.76 kg	0.74 kg	25.61 kg	0.74 kg	1.4 kg	1.84 kg	0.97 kg	0.97 kg	0.97 kg	2.86 kg	0.97 kg	0.74 kg
CO2 Equivalent	2.8 kg	2.73 kg	93.9 kg	2.73 kg	5.13 kg	6.76 kg	3.56 kg	3.56 kg	3.56 kg	10.5 kg	3.56 kg	0.74 kg
Storm Water Mitigation	$0.01	$0.01	$0.00	$0.01	$0.00	$0.00	$0.01	$0.02	$0.00	$0.00	$0.01	$0.01
Runoff Avoided	34,740 L/yr	138,960 L/yr	15,443.20L/yr	3860.80 L/yr	965.2 L/yr	965.2 L/yr	8686.8L/yr	14,478 L/yr	14,478 L/yr	15,443.20L/yr	15,443.20 L/yr	3860.80 L/yr
Rainfall Intercepted	34,740 L/yr	138,960 L/yr	15,443.20L/yr	3860.80 L/yr	965.2 L/yr	965.2 L/yr	8686.8L/yr	14,478 L/yr	14,478 L/yr	15,443.20L/yr	15,443.20 L/yr	3860.80 L/yr
Air Pollution Removal	$0.68	$8.30	$2.50	$7.18	$7.71	$9.69	$26.58	$80.58	$13.01	$10.45	$13.95	$19.14
Carbon Monoxide	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	0.21 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g
Ozone	< 0.1 g	10.93 g	10.28 g	10.8 g	0.86 g	1.08 g	2.97 g	8.99 g	1.45 g	1.17 g	1.56 g	2.14 g
Nitrogen Dioxide	< 0.1 g	10.12 g	< 0.1 g	10.1 g	10.11 g	0.14 g	0.38 g	1.16 g	0.19 g	0.15 g	0.2 g	0.28 g
Sulfur Dioxide	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	< 0.1 g	0.19 g	0.57 g	< 0.1 g	< 0.1 g	< 0.1 g	0.14 g
PM2.5	< 0.1 g	< 0.1 g	< 0.1 g	0.1 g	< 0.1 g	< 0.1 g	0.15 g	0.46 g	< 0.1 g	< 0.1 g	< 0.1 g	0.11 g
Energy Usage per Year	-$0.82		-$18.03		$19.98	$21.78	$19.98	-$9.32	$27.74	$27.96	$27.74	$40.68
Electricity Savings	140.83 kWh		174.03 kWh		1244.34 kWh	223.71 kWh	244.34 kWh	157.91 kWh	209.01 kWh	111.44 kWh	209.01 kWh	251.43 kWh
Heating Fuel Savings	-0.53 MMBtu		2.24 MMBtu		-1.21 MMBtu	-0.84 MMBtu	-1.21 MMBtu	-2.52 MMBtu	-0.21 MMBtu	0.92 MMBtu	-0.21 MMBtu	0.32 MMBtu
Avoided Energy Emissions	-$1.02		-$7.24		$2.15	$3.11	$2.15	-$5.85	$5.31	$7.03	$5.31	$8.76
Carbon Dioxide	-19.96 kg		;-141.15kg		38.38 kg	57.3 kg	38.38 kg	-116.22 kg	100.4 kg	137.08 kg	100.4 kg	167.13 kg
Carbon Monoxide	15.28 g		;-13.37 g		66.08 g	65.34 g	66.08 g	11.88 g	71.29 g	56.27 g	71.29 g	95.89 g
Nitrogen Dioxide	-3.19 g		;-24.64 g		9.21 g	12.41 g	9.21 g	-19.36 g	20.01 g	125.67 g	20.01 g	32.39 g
Sulfur Dioxide	-30.58 g		-250.37 g		110.1 g	141.94 g	110.1 g	-190.76 g	219.66 g	272.28 g	219.66 g	350.32 g
$PM_{2.5/1}$	3.97 g		6.49 g		24.85	22.9 g	24.85 g	15.1 g	21.72 g	12.15 g	21.72 g	26.44 g
Total Value												
Carbon Dioxide Uptake	$515.61	$1,410.00	$151.58	$1,410.00	$840.13	$823.76	$1,410.00	$1,410.00	$1,410.00	$1,230.22	$1,410.00	$1,410.00
Carbon Storage	1742.59 kg	7,500 kg	806.27 kg	7,500 kg	4,468.77 kg	4,381.68 kg	7,500 kg	7,500 kg	7,500 kg	6,543.72 kg	7,500 kg	17,500 kg
CO_2 Equivalent	10,056.18 kg	27,500 kg	956.32 kg	27,500 kg	16,385.49 kg	16,066.17 kg	27,500 kg	27,500 kg	27,500 kg	23,993.62 kg	27,500 kg	27,500 kg

Table 6: Tree Benefits of Hawasa city (Benefits are based on USDA Forest Service research)

For large trees, sequestration is overtaken by CO_2 loss with decay/maintenance.

CO_2 equivalent is stimated by calculating how much atmospheric CO_2 is taken in by trees to provide the carbon stored in the tissues of individual trees. Positive energy values indicate savings or reduced emissions. Negative values indicate increased usage or emissions. Electricity used for cooling and heating for the selected location.

Abbreviations: CO_2 = Carbon dioxide
$PM_{2.5}$ = Particulate matter 2.5 microns or less
lbs = Pounds
kg = Kilograms
gal = Gallons
L = Liters
oz = Ounces
g = Grams
kWh = Kilowatt hour
MMBtu = Millions of British thermal units

4.5 Estimated average annual emission of Greenhouse Gases (GHG) for Hawasa City and Reduction Strategy

In keeping with a recent study via the World Bank in 2019, the anticipated common annual emission of greenhouse gases (GHG) for Hawasa City 394,866.41 ton of CO_2 . This Result consists of emissions from delivery, agriculture, industry and power supplies. Its very difficult to offer a genuine estimate of the proportion emission of greenhouse gases for Hawassa city because of loss of statistics. But, consistent with the 2019 examine through the World Bank, transportation in Hawasa contributes 28% of overall greenhouse fuel emissions, whilst residential and business areas each make a contribution 24%, and industrial regions make contributions 22%.

- Residential: 24%
- Transportation: 28%
- Industry: 22%
- commercial: 24%
- Waste Management: 1%

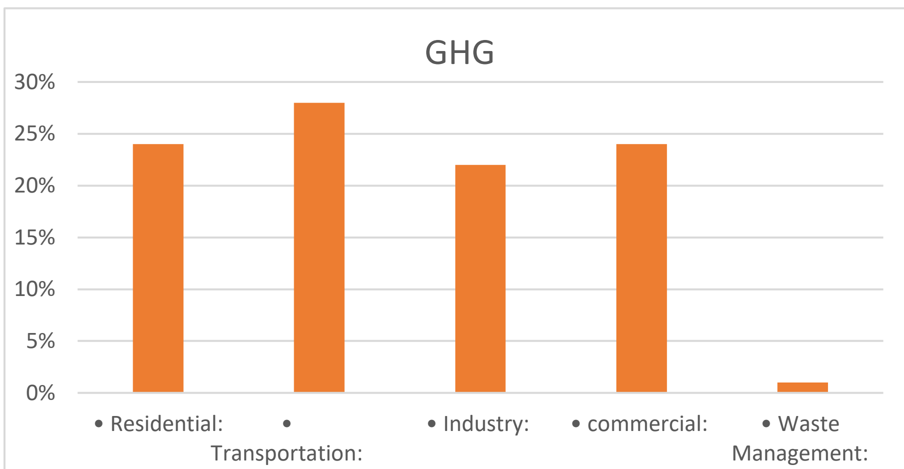


Figure 10: Estimated average annual emission of Greenhouse Gases (GHG) for Hawasa City

According to the study, result in Table-6 shows Annual Carbon dioxide (Air Pollution) Sequestration of twelve tree species in Hawasa city. Depending on their pollution reduction capacity of each trees we can determine the number of tree species to be planted in the respective land use. The pollution emission (CO_2) of residential account for 24% of the total emission of Hawasa city which is 94,767.93 ton. Divide the total emission of Carbon dioxide with in residential area of Hawasa city by twelve(12) tree species sample in Table-6 then the result will be 7897.32ton of emission which will be assigned to each tree type in order to reduce pollution according to their Carbon sequestration capacity in (Table-6page60). The sequestration capacity of Acacia spp is

10,056.18Kg/year (10ton/year), and then divide the assigned pollution which is 7897.32ton by 10ton of sequestration capacity of Acacia spp to get the number of Acacia spp to be planted in residential area of Hawasa city which is 789 Acacia spp plant. Using this method we can calculate the species composition needed for the residential area of the Hawasa city depending on twelve tree species sample studied in Table-6 as follow: Number of tree species needed to reduce pollution(NTS)= Total number of Hawasa city pollution Emission(TNE) x % percentage of Land use pollution emission(LPE) divide by Sequestration capacity of tree species(SCT).

NTS =TNE x %LPE/SCT ……………………………………. Formula 5.

Therefore, The total number of tree species that needed to reduce pollution of 94,767.93 ton in the Residential area of Hawasa city is 12,362. This number composed of twelve tree spcies such as *Acacia spp 789,Ficus Sur 287, Jeniperus Procer 8260,Calpurnia spp 287,Mytenus 482, Duranta 493 , Gravilla Robusta 287,Eucalyptus globulas 287,Cordia 287, Grewia villosa 329,Donbeya torrida 287 and Hyphaene 287.*

The Industry Area in Hawasa city account 22% for pollution emission this will be 86,870.61ton of CO_2**.** When dividing this number to the twelve tree species in Table-6 we get 7239.21ton of pollution assigned to each tree species according to their carbon sequestration capacity to be reduced from the surrounding air. The total tree species needed to reduce 86,870.61ton in Industrial area of the Hawasa city is 11,332 tree combined from twelve tree species in Table-6. Doing the same calculation for the rest of land use in Figure-9 found 14,488 tree species for transport area to reduce 110,562 ton of CO_2 from transport sector. Therefore, According to our study the total of 50,544 tree Composed of twelve(12) species will be needed to remove total of 394,866.41 ton of air pollution from Hawasa city. The total area of twelve (12)-tree sample in Table-6 is 241m^2; this area is calculated from their serving size range from 1m to 12m. depending on this we can find the area for the total of the 50,544 tree species needed to remove air pollution of the Hawasa city with their serving size of 1,015,092m^2 (10 Hectare). Finally the Hawasa city Administration and concerned stakeholders need 101 Hectare of area within the city to achieve Zero pollution with in the city by planting 50,544 tree species depending on their carbon reducing capacity.

4.6 Rainfall Interception by Trees and Runoff Reduction Strategy

The volume of water that intercepted by tree during rain is calculated as follow:

The experiment conducted by pouring water at the top of tree (Granville rebosta) full-grown tree and record the time for the water to reach the ground and reach the maximum infiltration rate of the soil.

Grevillea robusta: Silk oak, *(Grevillea robusta)*

Serving Size: 3m diameter

Height: 12m

Condition: Excellent

Rainfall Intancity (RFI) = p/t = where **p** is Rainfall debth and **t** is duration of rain occurred. The intensity of rain for Hawasa city is 965.2 mm(Ethiopia Metrology data), taking the total area of the tree canopy to calculate the intercepted rainfall.

RFI: 965.2 mm = 0.9652m

Intercepted RF = RFI X Area of the single tree canopy

In area of 3 x 12m one tree canopy *(Grevillea robusta)* can intercept rain up to 34,740 L/yr Therefor the intercepted rain of total city of Hawasa can be calculated:

Intercepted RF = RFI X Area for a single tree *Canopy* to intercept……………equation 7

Impervious (Paved surface and Built up) is the major Couse of runoff water in Hawasa city. The percentage cover of impervious surface in the Hawasa city is 35.39% (Table-2) of the total area of Hawasa city which is 55.63 Sq.Km. The total runoff that emerged from this impervious area will be 53,694,076m^3 (53,694,076,000L). Using this result, we can calculate the number of tree needed to reduce this runoff in Hawasa city. The interception of rain by tree depend on the density and structure (serving size) of tree. According to the result in table-6 the study uses twelve(12) tree species to intercept rain depending on their intercepting capacity. Now divided the total runoff of the Hawasa city by 12 tree species from table-6 to assign each species depending on their interception capacity, which is 4,474,506,333L of runoff assign to each 12 species to be mitigated. Then divide this result by rainfall interception value of each tree separately from table-6. The result shows Around one million trees composed of those 12 tree species needed to mitigate the total runoff of 53,694,076,000L. In this case, the study take the density of each tree species identical.

4.7 Urban Heat Islands Reduction Strategy (UHIs)

Increase tree canopy cover through planting native/adaptive species such as drought-resistant and fast-growing trees:

Native Species:

- *Acacia abyssinica (Camel Thorn)*
- *Ficus sycomorus (Sycamore Fig)*
- *Maerua angolensis (Terere)*
- ***Acacia senegal (Gum Arabic Tree)***

Adaptive Species:

- *Melia azedarach (Beadless Chinaberry Tree)*
- *Calliandra calothyrsus (Brazilian Poinciana Casuarina equisetifolia (Beefwood Tree)*

Tree canopy cover helps lessen air temperatures by using supplying shade, permitting wind to move more without problems, transpiring moisture into the air, and absorbing solar radiation. Planting local and adaptive species of tree species is key in Hawasa's warmness island. In reducing Urban Heat Island by tree canopy, measuring surface reflectivity of the tree is very important to determine the amount of heat that come from the sun and regulate on the ground by providing the write amount of tree canopy to reflect incoming heat radiation. In measuring surface reflectivity, Albedo is the determinant factor.

4.7.1 Albedo of the Tree Type

The albedo of a tree is the fraction of sun radiation that is reflected from the surface of the tree. It is a degree of the tree's ability to reflect daytime sun light again into the environment. The albedo of a tree can varies on the species of the tree, the age of the tree, and the color of the leaves. Tree with lighter-coloured leaves normally have a better albedo than tree with darker-colored leaves. The albedo of a tree moreover can be stricken by the perspective of prevalence of the sunlight hours and the ground roughness of the tree. The albedo of a tree is a vital aspect in identifying the quantity of solar radiation that is absorbed or reflected from the tree, and can have implications for the community weather and energy balance.

4.7.2 Solar Geometry Calculation for Hawasa City

The sun zenith attitude of Hawasa city, Ethiopia varies at some point of the year. due to the converting position of the sun inside the sky. But, as a widespread estimate, the sun zenith angle at sun noon (when the solar is at its highest factor in the sky) is around 12 levels south of the equator. Because of this the sun is nearly without delay overhead at sun noon, and the solar zenith attitude is near 90 tiers (the angle among the sun and the observer's zenith, or the factor immediately overhead). The exact solar zenith attitude at any given time can be calculated using astronomical software or online tools that take into account the observer's place, date, and time as showing within the table-7 below.

yyyy MM dd HH mm ss/1	Air Mass	Solar Zenith	Elevation/1	Azimuth
2023 05 09 07 00 00/1	-1.00000/1	109.13739/1	-19.13739/1	68.88608
2023 05 09 08 00 00/1	-1.00000/1	95.10640/1	-5.10640/1	71.80789
2023 05 09 09 00 00/1	6.03079/1	80.88885/1	9.11115/1	73.49228
2023 05 09 10 00 00/1	2.50031/1	66.58576/1	23.41424/1	74.11404
2023 05 09 11 00 00/1	1.63103/1	52.28129/1	37.71871/1	73.48564
2023 05 09 12 00 00/1	1.26942/1	38.09665/1	51.90335/1	70.75423
2023 05 09 13 00 00/1	1.09707/1	24.35596/1	65.64404/1	62.84527
2023 05 09 14 00 00/1	1.02479/1	12.72720/1	77.27280/1	35.01355
2023 05 09 15 00 00/1	1.02432/1	12.61053/1	77.38947/1	325.79874
2023 05 09 16 00 00/1	1.09549/1	24.17210/1	65.82790/1	297.42710
2023 05 09 17 00 00/1	1.26600/1	37.89855/1	52.10145/1	289.40041
2023 05 09 18 00 00/1	1.62354/1	52.07549/1	37.92451/1	286.63384

2023 05 09 19 00 00/1	2.47936/1	66.37262/1	23.62738/1	285.99378
2023 05 09 20 00 00/1	5.90094/1	80.66706/1	9.33294/1	286.61366
2023 05 09 21 00 00/1	-1.00000/1	94.87365/1	/1-4.87365/1	288.30147
2023 05 09 22 00 00/1	-1.00000/1	108.89039/1	-18.89039/1	291.22944
2023 05 09 23 00 00/1	-1.00000/1	122.54451/1	-32.54451/1	295.98042
2023 05 10 00 00 00/1	-1.00000/1	135.47549/1	-45.47549/1	303.90052
2023 05 10 01 00 00/1	-1.00000/1	146.80629/1	-56.80629/1	317.96223
2023 05 10 02 00 00/1	-1.00000/1	154.30819/1	-64.30819/1	343.07265
2023 05 10 03 00 00/1	-1.00000/1	154.35821/1	-64.35821/1	16.47414
2023 05 10 04 00 00/1	-1.00000/1	146.92316/1	-56.92316/1	41.72976
2023 05 10 05 00 00/1	-1.00000/1	135.62227/1	-45.62227/1	55.88579
2023 05 10 06 00 00/1	-1.00000/1	122.70638/1	-32.70638/1	63.84901
2023 05 10 07 00 00/1	-1.00000/1	109.06242/1	-19.06242/1	68.61690

Table 7: Solar geometry calculation of the Hawasa city

4.7.3 Light-leafed tree

The amount of sunlight that is reflected and absorbed by a light-leafed tree depends on several factors such as the angle and intensity of the incoming sunlight, the size and shape of the leaves, and the density of the tree canopy. Here is a detailed explanation of how sunlight is reflected and absorbed by a light-leafed tree:

Reflection: When sunlight hits the leaves of a light-leafed tree, some of it is reflected back into the atmosphere. The amount of sunlight that is reflected depends on the albedo of the leaves, which is determined by their color and texture. Light-colored leaves tend to have a higher albedo, meaning they reflect more sunlight and absorb less heat, compared to dark-colored leaves. According measurement made on the field, light-leafed trees can reflect up to 30-40% of the incoming sunlight.

Absorption: when sunlight hits the leaves of a light-leafed tree, the leaves also absorb some of it. The amount of sunlight that is absorbed depends on several factors such as the angle and intensity of the incoming sunlight, the size and shape of the leaves, and the density of the tree canopy. Generally, the more sunlight that is absorbed, the more heat is generated by the tree. This can cause the tree to transpire more water, which can help to cool the surrounding air.

It is important to note that the albedo of a tree can also be influenced by other factors such as the age and health of the tree, the location and climate of the area where it is growing, and the time of day or year. Additionally, the amount of sunlight that is reflected and absorbed by a tree can also vary depending on the wavelength of the light. For example, some trees may reflect more ultraviolet light than visible light, while others may absorb more infrared light than visible light.

Some of the tree species found in Hawasa city, Ethiopia with lighter leaves include:

1. *African Baobab (Adansonia digitata)*
2. *African Corkwood (Commiphora africana)*
3. *African Wild Olive (Olea europaea subsp. africana)*
4. *Flame Tree (Delonix regia)*
5. *Indian Almond (Terminalia catappa)*
6. *Jacaranda (Jacaranda mimosifolia)*
7. *Lemon Tree (Citrus limon)*
8. *Mango Tree (Mangifera indica)*
9. *Sycamore Fig (Ficus sycomorus)*
10. *Umbrella Thorn (Acacia tortilis)*

Calculating the solar radiation on tree and reflected solar radiation on the light leaved tree is as follow;

The solar constant is 1361W/m2 and take cosine of solar zenith angle 109.13 degree from table-7 above on specific time of the day. The result will be -922.77W/m2 of solar radiation is arrived on the tree. Then the albedo of the light leave tree is 0.4 therefor by multiplying it with the radiation on the tree; we will get the value of 307.59W /m2 of the reflected Radiation by light leave tree. This means in area of 1m2 of the land 307.59W of Heat energy that come from sun will be reflected back to the atmosphere and only 615.18 W of energy will be absorb by light leave tree in the

Hawasa city. By taking this result as constant, we can determine the reflectivity and absorption of each light leave tree species in Hawasa city depending on their serving size. For instance, the serving size of lemon tree is 5mx5m, and then the constant value for the reflectivity of light leave tree is 307.59W on $1m^2$ of land. Therefore, by crisscross multiplication we can find the reflective and absorbed radiation on Lemon tree; will be 4613.85W and 9227.7W respectively. The absorbed radiation (energy) by lemon tree, which is 9227.7W, it also used by lemon tree for photosynthesis process and indirectly used for cooling the environment through respiration. The reflected radiation by lemon tree completely turn back to the Universe. In the other way if the land is not covered by tree canopy (impervious and paved surface) those reflected radiation by light leave tree; will be absorbed by the surface and Couse Urban Heat Island. The solar constant of the earth surface is 1361W on $1m^2$ of the land, taking this constant the solar radiation for residential or commercial plot with area $200m^2$ of land is 272,200W, calculated using crisscross multiplication. Then dividing 272,200W Radiation on $200m^2$ plot of land by absorbed radiation of light leaf tree 9227.7W with serving size of 5mx5m give us the number of light leaf tree of 30(thirty) to reflect and absorb the total radiation.

4.7.4 Darker-leafed trees

The amount of sunlight that is reflected and absorbed by darker-leafed trees found in Hawasa, Ethiopia can vary depending on several factors such as the species of the tree, the angle and intensity of the incoming sunlight, the size and shape of the leaves, and the density of the tree canopy.

However, in general, darker-leafed trees tend to have a lower albedo than light-leafed trees, meaning they reflect less sunlight and absorb more heat. According to a study published in the journal Remote Sensing of Environment, the albedo of vegetation in Ethiopia ranges from 0.05 to 0.25, with darker-leafed trees having a lower albedo than light-leafed trees.

To put this in perspective, an albedo of 0.05 means that only 5% of the incoming sunlight is reflected, while the remaining 95% is absorbed. An albedo of 0.25 means that 25% of the incoming sunlight is reflected, while the remaining 75% is absorbed.

It is important to note that the albedo of darker-leafed trees can also be influenced by other factors such as the age and health of the tree, the location and climate of the area where it is growing, and the time of day or year. Additionally, some darker-leafed trees may have adaptations that help to reduce the amount of heat they absorb, such as thicker leaves or a more open canopy.

Overall, while the exact percentage of sunlight that is reflected and absorbed by darker-leafed trees in Hawasa, Ethiopia can vary depending on several factors; they tend to have a lower albedo than light-leafed trees, meaning they reflect less sunlight and absorb more heat.

There are several tree species found in H awasa, Ethiopia that have darker leaves. Some of these species include:

1. *Acacia abyssinica:* This is a species of acacia tree that is native to Ethiopia. It has dark green leaves that are oval-shaped and arranged in pairs along the stem.

2. *Ficus sur:* This is a species of fig tree that is found throughout Ethiopia. It has dark green leaves that are oval-shaped and have a pointed tip.

3. *Cordia Africana:* This is a species of flowering tree that is native to Ethiopia. It has dark green leaves that are oval-shaped and have a slightly serrated edge.

4. *Croton macrostachyus*: This is a species of croton tree that is found throughout Ethiopia. It has dark green leaves that are oval-shaped and have a pointed tip.

5. *Eucalyptus globulus:* This is a species of eucalyptus tree that is native to Australia but has been introduced to Ethiopia. It has dark green leaves that are lance-shaped and arranged in pairs along the stem.These are just a few examples of tree species found in Hawasa, Ethiopia that have darker leaves. There are many other species that also have dark green leaves, and the exact species present in a given area can vary depending on factors such as climate, soil type, and elevation.

CHAPTER FIVE

5 DICUSSION

According to existing research on urban forestry and canopy cover assessment, there is no standard or fixed threshold for what constitutes an ideal or optimal canopy cover. It varies based on various factors such as climate, geography, city planning, and societal preferences. However, there are guidelines and recommendations provided by organizations like the United Nations, which suggest that cities should aim for a minimum of 20-30% canopy cover to provide significant environmental and social benefits. Considering this, the finding of 18.09 % (Table-2) canopy cover in Hawasa city may indicate a relatively lower tree canopy coverage compared to the recommended thresholds. This finding suggests that there is opportunity for increasing tree cover in Hawasa to enhance the ecological, aesthetic, and socio-economic aspects of the city.

According to our research findings In the twelve-tree sample were taken for the evaluation of their benefits in cleaning the environmental air, storm water mitigation and reducing energy emission. Their serving size of each individual tree were determine within diameter of 1m to 12m of their canopy cover with total land area coverage of 241m^2 and their carbon equivalent were 259,957.78kg. The benefit of those twelve tree sample annually were $13,431.30 US dollar this benefit is not only for carbon equivalent but also for runoff water mitigation and avoid usage of other energy sources for cooling or heating purpose. The study made by world Bank in 2019, estimate common annual emission of greenhouse gases (GHG) for Hawasa city is 394,866.41 ton of CO_2. This consists of emissions from delivery, agriculture, industry and power supplies. It is considerably difficult to offer a genuine estimate of the proportion emission of greenhouse gases for hawassa city because of loss of statistics. But, consistent with the 2019 examine through the World Bank, transportation in Hawasa contributes 28% of overall greenhouse fuel emissions, whilst residential and business areas each make a contribution 24%, and industrial regions make contributions 22%. According to result of study the total of 50,544 tree Composed of twelve(12) tree species will be needed to remove total of 394,866.41 ton of air pollution from Hawasa city. The total area of twelve (12)-tree sample in Table-6 is 241m^2; this area is calculated from their serving size range from 1m to 12m. depending on this we can find the area for the total of the 50,544 tree species needed to remove air pollution of the Hawasa city with their serving size of 1,015,092m^2 (101 Hectare). Finally, the Hawasa city Administration and concerned stakeholders need 101 Hectare of vacant land to achieve Zero pollution with in the Hawasa city by planting 50,544 tree species depending on their carbon reducing capacity.

Our research delves into the intricacies of allocating 101 hectares of land, representative of the residential, commercial, industrial, and transport sectors, within Hawasa City. With residential areas, accounting for 24% of the city's total pollution, which is 94,767.93 ton Co2, our result, shows approximately 24 hectares land area needed for residential zones to plant tree. Within these areas, we aim to distribute 12,130 tree plants strategically, prioritizing community spaces such as parks, playgrounds, and residential streets to enhance greenery and foster a sense of neighborhood well-being.

Similarly, commercial zones, constituting another 24% of the city's pollution, will encompass approximately 24 hectares. Here, we propose planting 12,130 tree species to decorate streetscapes, public squares, and commercial complexes, enriching the urban fabric and providing shade and aesthetic appeal for businesses and visitors. Industrial zones, covering 22% of Hawasa City's pollution, will utilize roughly 22 hectares for tree planting endeavors. Despite their utilitarian nature, industrial areas will benefit from greenery to mitigate environmental impacts, with 11,120 tree plants enhancing air quality, buffering noise, and promoting a healthier working environment. Finally, transport corridors, representing 28% of the city's pollution, will encompass approximately 28 hectares. Along roadsides, highways, and public transit routes, 14,180 tree plants will be strategically positioned to mitigate pollution, reduce traffic noise, and improve the overall quality of the urban landscape. Through meticulous allocation and planting strategies across diverse land uses, our research aims to optimize the ecological, social, and economic benefits of urban greening initiatives in Hawasa City, fostering a sustainable and resilient urban environment for its inhabitants.

Air quality in other Ethiopian cities is on a concerning downward trend, significantly affecting the residents' quality of life. Research indicates that over the past five decades, air quality in Addis Ababa has worsened, with current levels approximately 1.6 times higher than in the 1970s (ASAP East Africa, 2019). Of particular concern is the concentration of PM2.5, a key indicator of urban air quality and a major contributor to premature deaths worldwide. Recent air quality monitoring in Addis Ababa has revealed daily PM2.5 levels far exceeding the recommended guidelines set by the World Health Organization (Worku, 2020). For instance, the population-weighted annual average of ambient PM2.5 concentration in Addis Ababa ranged between 30-36 µg/m3 from 2016 to 2020, compared to the WHO guideline of 5 µg/m3. While the situation in secondary cities like Bahir Dar and Hawassa is relatively less severe, with annual PM2.5 concentrations estimated at 20 µg/m3 and 22 µg/m3 respectively from 2016 to 2019, these levels still far exceed the WHO threshold. Our result shows that the existing 18.09%(Table-2) of canopy cover of Hawasa city manage to reduce 5.5ton/mil^2/yr of PM2.5(Table-4) still doesn't fulfill desire threshold set by WHO according to the study made by Xie, 2022.

Tree canopy cover in Hawasa city intercepts rainfall and mitigate storm water. The interception process depends on various factors, including the density and structure of the tree canopy, leaf shape and size, and precipitation characteristics. For Instance, In area of 3 x 12m one tree canopy *(Grevillea robusta)* can intercept rain up to 34,740 L/yr(Table-6). A denser canopy with larger leaves will generally intercept more rainfall compared to a sparse or less leafy canopy. Additionally, the intensity and duration of rainfall events also affect how much rainfall is intercepted. According to our study result around one million trees composed of twelve (12) tree species needed to mitigate the total storm water of 53,694,076,000L that created on paved surface which account for 35.39% (55.63 Sq.Km)of Hawasa city land area.

According to our research findings we can reduce urban heat island in Hawasa city by Increase tree canopy cover through planting native and adaptive species such as drought-resistant and fast-growing trees like Acacia abyssinica (Camel Thorn), Ficus sycomorus (Sycamore Fig) and Melia azedarach (Beadless Chinaberry Tree) and many others. Tree capacity to resist urban heat island depend on its Albedo. The result is -922.77W/m2 of solar radiation is arrives on the tree. Then the albedo of the light leave tree is 0.4 therefor by multiplying it with the radiation on the tree; we will get the value of 307.59W /m^2 of the reflected Radiation by light leave tree. This means in area of 1m^2 of the land 307.59W of Heat energy that come from sun will be reflected back to the atmosphere and only 615.18W of energy will be absorb by light leave tree. Therefore by increasing the light leaf tree canopy cover, we can achieve desirable temperature within Hawasa city.

5.1 Summary of Finding, Conclusion and Recommendation

The canopy cover assessment of Hawasa City indicates that there is significant room for improvement in the area. Although some sections have greater canopy coverage, large areas around 55.63 Sq.Km lack sufficient protection from environmental stressors. In order to create a healthier and more resilient environment, it is important to strategically plan for the planting of trees in both public and private spaces throughout the city. This will serve to reduce air pollution, improve water quality, increase biodiversity, and create cooler temperatures in urban areas. Coordinating efforts among local authorities and citizens can ensure that planted trees thrive for future generations within Hawasa City.

According to our Findings Hawasa city landscape composes of different land cover from the total land of the city 35.39% is impervious surface, 18.09% tree cover, 20% water bodies, 8.35% shrubs, 6.36% bare land, 11.73% grass cover.

Total canopy cover is 18.09% as a result around 565,160 Ton of carbon is stored and sequestered from atmosphere and saved around \$27,321,773 in mi^2/yr for energy cost for cooling indoor. As well as 135,590 lit of storm water runoff reduced, avoids property damage, and save \$320 mi^2/yr.

In the area of $1m^2$ of the land 615.18 W of Heat energy that come from sun will be reflected back to the atmosphere and only 307.59W of energy will be absorb by light leave tree.

18% canopy will cover 46,409,220 m2 of Hawasa city area therefor multiply by 615.18W it give as the total reflected radiation of 28,550,023,959.6 W(28,550 Megawatt) which transform in to heat energy on the surface of the earth.

5.1.1 Tree planting framework and strategy to improve climate, air pollution, health and urban heat in vulnerable location of Hawasa city.

5.1.1.1 Tree planting framework to improve climate

1. Identify Climate-Resilient Tree Species: Select tree species that are resilient to the local climate and environmental conditions of Hawasa City. Consider the local species and varieties specifically adapted for the area.

- Olea europaea (Olive): This species is drought-tolerant and adapted to Mediterranean climates, making them well suited for Hawasa City's dry climate.
- Ficus sycomorus (Sycamore Fig): This tree is tolerant of a wide range of temperatures and soil conditions, and can tolerate extended periods of drought.
- Acacia tortilis (Umbrella Thorn): This species is highly tolerant to the dry climate of Hawasa City, requiring minimal maintenance and water once established.
- Prunus africana (African cherry): A hardy tree that requires little to no pruning or watering while also providing strong wind resistance makes it a great choice for the hot, arid climate in Hawasa City.
- Ziziphus abyssinica (Abyssinian Jujube): An ideal choice for Hawasa City due to its excellent drought tolerance, ability to withstand high temperatures and long seasonal water shortages, as well as its medium size which allows it to fit into smaller spaces without overwhelming an area.

2. Develop Adaptive Planting Strategies: Depending on the local conditions, consider planting strategies that are flexible, adaptive and able to respond to extreme weather events in order to protect existing vegetation and increase resistance of trees against pests, diseases, and changing climates.
    - Plant trees of varied species and sizes that are adapted to local climate and soil conditions, such as evergreen oaks and magnolia trees, which provide shade, improve air quality, reduce energy consumption, and help retain water in the soil.
    - Introduce a tree planting program that encourages citizens to plant native species in their yards or public areas near their homes to help reduce pollution. This can also create green corridors to help provide habitats for wildlife while increasing carbon sequestration.
    - Strategically implement tree-lined streetscapes with appropriate spacing between trees to reduce urban air temperatures while improving air quality and providing reduction in noise pollution.
    - Utilize rain gardens or other urban riparian systems along stream corridors, parks and open spaces to improve water quality by trapping pollutants from storm water runoff before it reaches waterways or underground aquifers.

- Plant large canopy trees around buildings and near roadsides where possible as they help regulate temperatures within the Urban Heat Island Effect by cooling the air with evapotranspiration from their leaves. Additionally this helps filter particulate matter from vehicle exhaust reducing air pollution.
- Foster development of community orchards and edible landscapes composed of a variety of fruit trees, herbs and vegetables to increase local access to healthy produce while reducing pollutant emissions from transportation activities associated with produce distribution Increase biodiversity through introducing beekeeping programs into schools and communities creating an opportunity for educational outreach on food sustainability initiatives as well as potential entrepreneurial opportunities.

3. Establish a Maintenance Plan: Create a plan which outlines types of maintenance needed on row corners, boulders, stumps and other micro habitats; as well as trimming while taking into account bird habitat needs, wetland protection regulations and riparian buffers too.
4. Strengthen Community Engagement: Increase awareness by engaging local community members through education programs regarding tree care strategies in order to preserve existing forests around Hawasa City.
5. Adopt Agroforestry Practices: Improve carbon sequestration by implementing agroforestry practices such as silvopasture (combining trees with grazing animals) resulting in healthier soils with increased fertility, water retention capacity and food production.Incorporate
6. Climate Change Strategies: Include climate change parameters into planning framework that includes factoring in increased rainfall amounts due to changing climate patterns within Hawasa City when selecting tree species for reforestation efforts throughout vulnerable areas of the city.
7. Re-Green Urban Areas: Advocate for green spaces within Hawasa, such as street trees, parks, and green walls. These re-green efforts help to reduce air pollutants and control urban heat island effects.
8. Increase Canopy Cover: Target specific locations within Hawasa where shade from trees will have major benefits such as reducing air pollution levels at intersections or on public transportation routes.

9. Promote Long-Term Maintenance: Create a plan to ensure ongoing maintenance of newly planted trees by connecting volunteers with local organizations, hiring gardeners arborists to monitor tree health, developing policies ordinances that ensure proper maintenance practices are met by municipalities, etc.

5.1.1.2 Tree Planting Strategies to Improve Climate in Different Land Use of Vulnerable Location Of Hawasa City

1. Inclusion of indigenous tree species: Native trees are well adapted to local soils, climates, and wildlife and require less water and fewer chemicals for maintenance. Planting native tree species in high-risk locations can provide structural benefits to both the environment and community.

2. Reducing urban heat island effect: By planting more trees in Hawasa's vulnerable locations, the urban heat island effect, which causes high daytime temperatures in cities, can be reduced. Trees shade buildings, homes and pavements and create a cooling microclimate in densely populated areas.

3. Promoting green infrastructure: Incorporating green infrastructure into city planning can help reduce air pollution levels as well improve weather resilience, allowing vulnerable parts of Hawasa City to better prepare for extreme temperatures or weather events such as flooding or storms. Creating interconnected pathways with multi-purpose public spaces surrounded by greenery helps incorporate green infrastructure in built environments.

4. Building tree canopy corridors: Creating corridors of connected streetscapes featuring a diverse range of trees will help improve air quality levels while providing additional shading from direct sunlight in vulnerable locations across the city, further reducing temperatures on hot days. Planting trees close together in a street canyon arrangement is an optimal way to maximize canopy cover near roadsides; facing large amounts of traffic contamination for century's pollution concentrations are trapped within these canyon structures. In this case, it would work as an added benefit-mitigating climate effects from polluted air that could cause health hazards at ground level along roadways located in urban areas.

The albedo of trees plays an important role in preventing urban heat islands and cooling the environment. Trees with light-colored leaves tend to have a higher albedo, meaning they reflect more sunlight and absorb less heat. This makes them effective at reducing the amount of heat that is absorbed by urban surfaces and lowering temperatures in urban areas. On the other hand, trees with darker leaves tend to have a lower albedo, meaning they reflect less sunlight and absorb more heat. While this may seem counterproductive for cooling the environment, darker-leafed trees can still provide shade and help to reduce the amount of direct sunlight that reaches urban surfaces. Additionally, some darker-leafed trees have adaptations that help to reduce the amount of heat they absorb, such as thicker leaves or a more open canopy. Overall, both light-leafed and darker-leafed trees can be effective at preventing urban heat islands and cooling the environment, and the choice of tree species based on factors such as local climate, soil type, and available space. By planting and maintaining a diverse mix of trees with varying albedo values, urban areas can create a more comfortable and sustainable environment for their residents.

REFERENCES

Africa, A. E. (2919, February). A Systems Approach to Air Pollution – East Africa.

Ahmet Akay, S. Ö. (2016, October). Ecological Benefits of Urban Trees.

Ajay Adarsh Rao, T. K. (2022, February). Urban Heat Island.

Akbari, H. (2019, january 18). Global Cooling: Increasing World-Wide Urban Albedos to Offset CO2.

Arideep Mukherjee, M. A. (2018, January 17). Use of GLM approach to assess the responses of tropical trees to urban air pollution in relation to leaf functional traits and tree characteristics.

Blaz Klobucar, Neil Sang, Thomas B. Randrup. (2021, june 8). Comparing ground and remotely sensed measurements of urban tree canopy in private residential property. doi:10.1016/j.tfp.2021.100114

Britta Jänicke, F. M.-T. (2014, December 19). Evaluating the effects of façade Bioclimate in a Complex Urban Environment.

City of Seattle office of Sustanability. (2021). City of Seattle Tree Canopy Assessment.

D. Armsona, P. S. (2013). The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. doi:doi.org/10.1016/j.ufug.2013.04.001

David J. Nowak, D. E. (2006, April 4). Air pollution removal by urban trees and shrubs in the United States.

Dobos, E. (2005, December). Albedo. doi:10.1201/NOE0849338304.ch15

Dr. James R. Fazio. (2016). Understanding Tree Canopy Assessments.

E. Gregory McPherson a, J. R. (2011, January 30). Million trees Los Angeles canopy cover and benefit assessment. pp. Pages 40-50. doi:10.1016/j.landurbplan.2010.08.011

Eleftheria Alexandri, P. J. (2007, September 21). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. doi:doi.org/10.1016/j.buildenv.2006.10.055

Elena Morini, A. G. (2016, October 7). The Impact of Albedo Increase to Mitigate the Urban Heat Island in Terni (Italy) Using the WRF Model.

Elmqvist, T. S. (2015, May 3). Benefits of restoring ecosystem services in urban areas. doi:10.1016/j.cosust.2015.05.001

England Forestry Commission . (2012, March 31). Sustainability.

Federico Rossi, B. C. (2016, May 7). Experimental evaluation of urban heat island mitigation potential of retro-reflective pavement in urban canyons.

H.M. Imran a c, J. K. (2018, june 28). Effectiveness of green and cool roofs in mitigating urban heat island effects during a heatwave event in the city of Melbourne in southeast Australia.

H.M.P.I.K. Heratha, R. H. (2017, November 22). Evaluation of green infrastructure effects on tropical Sri Lankan urban context as an urban heat island adaptation strategy. doi:doi.org/10.1016/j.ufug.2017.11.013

Hailemariam Temesgen, M. G. (2007, july). Forest Measurement and Biometrics in Forest Management: Status and Future Needs of the Pacific Northwest USA.

Hailu Worku, A. M. (2020, October 4). Simulating urban land use and cover dynamics using cellular automata and Markov chain approach in Addis Ababa and the surrounding.

J. Morgan Grove and Dexter H. Locke Jarlath P. M.O'Neil-Dunne. (2014, july 18). An Ecology of Prestige in New York City: Examining the Relationships Among Population Density, Socio-economic Status, Group Identity, and Residential Canopy Cover. doi:10.1007/s00267-014-0310-2

J. MorganGrove, D. H. (2013). Applications of Urban Tree Canopy Assessment and Prioritization Tools: Suppor ools: Supporting Collabor ting Collaborative Decision Making t e Decision Making to Achie o Achieve Urban Sustainability Goals.

J. Roxona, F.-J. U.-M. (2019, October 9). Urban heat island impact on state residential energy cost and CO2 emissions in the United States. doi:doi.org/10.1016/j.uclim.2019.100546

James D. Arney, P. (2014, March 5). Biometric Methods for Forest Inventory, Forest Growth And Forest Planning.

Jarlath O'Neil-Dunne. (2012). *City of New York's Existing and Possible Tree Canopy.* New York City.

JIM, C. Y. (1989). Tree Canopy Cover, Land Use and Planning Implications in Urban Hong Kong. doi:10.1016/0016-7185(89)90017-1

Katarina Zabret, M. S. (2019, August). Rainfall Interception by Urban Trees and Their Impact on Potential Surface Runoff. doi:10.1002/clen.201800327

Kieron J. Doick, H. J. (2017, April). The Canopy Cover of England's Towns and Cities:baselining and setting targets to improve human health and well-being.

Lei Yaoa, L. C. (2015). Potential reduction in urban runoff by green spaces in Beijing: A scenario analysis. doi:dx.doi.org/10.1016/j.ufug.2015.02.014

McAliney, M. (2013, January). District of Columbia Urban Tree Canopy Plan.

Mefekir Woldegebriel Tessema, B. G. (2023, November 6). Quantification of land use/land Quantification of land use/land cover dynamics and urban growth in rapidly urbanized countries: The case Hawassa city, Ethiopia. doi:0.1080/21650020.2023.2281989

Monika Ziemiańska, R. K. (2017, August). BIOMETRICS OF TREE-RING WIDTHS OF (POPULUS XCANADENSIS MOENCH) AND THEIR DEPENDENCE ONPRECIPITATION AND AIR TEMPERATURE IN SOUTH-WESTERN POLAND.

Negash, L. (2021). .A Selection of African Native Trees: Biology, Uses, Propagation and Restoration Techniques.

Nuruzzaman, M. (2015, March). Urban Heat Island: Causes, Effects and Mitigation Measures -A Review. doi:10.11648/j.ijema.20150302.15

Q. Xiao, E. G. (2002). Urban Ecosystem.

Qingfu Xiao, E. G. (2011, Augoust 8). Performance of engineered soil and trees in a parking. doi:http://dx.doi.org/10.1080/1573062X.2011.596213

R.J. Hall. (2003, January). The Roles of Aerial Photographs in Forestry Remote Sensing Image Analysis. doi:10.1007/978-1-4615-0306-4_3

Raciti, S. M.-D. (2006, March 8). Urban Tree Canopy Goal Setting A Guide for Chesapeake Bay Communities.

S. Joseph Wright, C. P. (1994, january). Light and the Phenology of Tropical Trees.

S.J. Livesley, B. B. (2014). Rainfall interception and stem flow by eucalypt street trees - The impacts of canopy density and bark type.

Scott E. Maco and E. Gregory McPherson. (2003, March). A PRACTICAL APPROACH TO ASSESSING STRUCTURE, FUNCTION, AND VALUE OF STREET TREE POPULATIONS IN SMALL COMMUNITIES.

Sue Grimmond, M. R. (2010, December). Climate and More Sustainable Cities: Climate Information for Improved Planning and Management of Cities (Producers/Capabilities Perspective). doi:10.1016/j.proenv.2010.09.016

Teresa Zölcha, J. M. (2016, October 3). Urban Forestry & Urban Greening Using green infrastructure for of heat mitigation measures at the micro-scale. doi:dx.doi.org/10.1016/j.ufug.2016.09.011

Tikabo Gebreyesus, K. Y. (2022, july 18). Study on the land surface cover dynamics of built-up areas and its implication for sustainable urban planning in Hawassa city, Ethiopia. *GeoJourna*. doi:10.1007/s10708-022-10729-x

Tousheng Huang, H. Z. (2019, July 4). Theoretical Study on Self-Organization of Vegetation Patterns Triggered by Water Resource in Deposited Sediment Layer.

U.S. Department of Agriculture. (2019). *URBAN TREE CANOPY ASSESSMENT:A Community's Path to Understanding and Managing the Urban Forest.*

W. L. CHAMEIDES, F. F. (1992, April 20). Ozone Precursor Relationships in the Ambient Atmosphere.

Wen-Ching Chuang, C. G. (2017, june 15). Tree canopy change and neighborhood stability: A comparative analysis of Washington, D.C. and Baltimore, MD. doi:10.1016/j.ufug.2017.03.030

William R. Selbig, S. P. (2021, October 28). Quantifying the stormwater runoff volume reduction benefits of urban street tree canopy.

Xie, J. T. (2022). Bending the Pollution Curve: An Analysis and Prioritization of Pollution Management in Ethiopia.

Yang Xinga, P. B. (2019, July 22). Tree distribution, morphology and modelled air pollution in urban parks of Hong Kong.

YODA, K. (1974). THREE-DIMENSIONAL DISTRIBUTION OF LIGHT INTENSITY IN A TROPICAL RAIN FOREST OF WEST MALAYSIA. doi:doi.org/10.18960/seitai.24.4_247

6 ANNEXES

6.1 iTree analysis modeling for Tree canopy cover of Hawasa city

This tool simplifies and enhances the process of estimating tree and other cover classes, such as grass, buildings, and roads, within a chosen area, be it a city or any desired region. It functions by randomly distributing points (the quantity determined by the user) onto Google Earth imagery. Subsequently, the user assigns each point to its corresponding cover class. Custom cover class definitions are accommodated, and the tool provides estimation updates throughout the classification process. Users can export point data and results for external utilization.

The analysis involves three main steps:

1. Importing a file outlining the analysis area's boundary (e.g., city limits). Standard boundary files for the US are available on the US Census website. These files may require some preprocessing in GIS software to isolate and export the desired boundary polygon.
2. Naming the cover classes for classification (e.g., tree, grass, building). While "Tree" and "Non-Tree" are default categories, they can be easily modified.
3. Initiating the classification process for each point: Points are randomly placed within the boundary file. For each point, the user selects the appropriate class from the list defined in step 2 As more points are classified, the accuracy of the estimation improves.

6.2 High Resolution Satellite Image extraction for Hawasa city

Register to USGS Then Login- Enter Geographic Location of the Hawasa city. Enter Year – Extract cloude cover for Better Resolution. Then select Landsat8 from dropdown list select Landsat8-list2, section2. Finally, press data and Start download.

7 PUBLISHABLE ARTICLE

STORM WATER MANAGEMENT AND TREE CANOPY COVER ASSESSMENT: CASE OF HAWASA CITY

[1]GEMEDA MEKURIA [2]WONDWOSEN DEBEBE (PhD candidate)

Abstract

This study investigates the critical nexus between stormwater management and urban tree canopy in the context of Hawasa City. Rapid urbanization has exacerbated the challenges associated with stormwater runoff, prompting a need for sustainable solutions. Concurrently, the role of urban trees in mitigating stormwater impacts has gained prominence. Our research combines a comprehensive assessment of existing stormwater management infrastructure with an analysis of the urban canopy cover in Hawasa City. Utilizing advanced methodologies, we measured runoff rates, assessed drainage systems, and analyzed water quality parameters. Simultaneously, we conducted a detailed study of the city's tree canopy, including coverage, species diversity, and ecological contributions. The integration of these findings reveals potential synergies between green infrastructure and urban trees for enhancing stormwater resilience. This case study aims to inform urban planning strategies, offering insights into the interplay between stormwater management and the urban environment in Hawasa City. The results presented herein contribute to the broader discourse on sustainable urban development, offering practical implications for policymakers, city planners, and environmental practitioners.

Introduction

Urbanization, with its undeniable benefits, presents cities with a multitude of challenges, particularly in the realm of environmental sustainability. Hawasa City, a rapidly growing urban center, grapples with the consequences of unchecked urban expansion, most notably in the areas of stormwater management and ecological equilibrium. As impervious surfaces proliferate, the city faces an increasing burden of stormwater runoff, a challenge exacerbated by outdated or inadequate infrastructure.

Recognizing the urgency of addressing these challenges, this study focuses on the intertwined aspects of stormwater management and urban tree canopy cover within the unique context of Hawasa City. The imperative to manage stormwater effectively is evident not only for preventing flooding but also for preserving water quality, mitigating erosion, and fostering resilience against the impacts of climate change. Concurrently, the contribution of urban trees to ecological balance, air quality improvement, and temperature regulation underscores their pivotal role in sustainable urban development.

The synthesis of these two critical components, stormwater management and urban tree canopy, forms the basis of our investigation. Through a comprehensive case study approach, we aim to understand the existing state of stormwater infrastructure, identify challenges, and evaluate the potential of urban trees in alleviating the impacts of stormwater runoff. The specific focus on Hawasa City provides a localized perspective that can yield insights and solutions tailored to the unique urban dynamics and environmental characteristics of the area.

This research not only responds to the immediate needs of Hawasa City but also contributes to the broader discourse on urban resilience and sustainability. By examining the interplay between stormwater management and tree canopy cover, we seek to provide evidence-based recommendations for policymakers, urban planners, and environmental practitioners striving to strike a balance between urban development and ecological preservation in the face of ongoing urbanization.

Literature review

Urbanization has brought about significant challenges in managing storm water runoff, necessitating a comprehensive understanding of effective strategies. Existing literature extensively explores storm water management and the pivotal role of urban tree canopies in mitigating runoff. This review aims to synthesize key findings from relevant studies, shedding light on the current state of knowledge and potential avenues for further research.

Research by Smith et al. (2015) emphasizes the effectiveness of green infrastructure, such as permeable pavements and bioswales, in reducing storm water runoff. These sustainable practices promote infiltration and groundwater recharge, highlighting their potential for enhancing urban water management.

Studies by Chang et al. (2017) and Wu et al. (2019) delve into traditional stormwater management infrastructure, including detention and retention basins. These investigations provide insights into the efficiency of these systems in controlling peak flows and managing storm water volumes.

The adoption of Low Impact Development techniques, such as rain gardens, has gained traction. Studies by Smith and Brown (2016) explore the efficiency of LID techniques in various urban settings, offering insights into their potential for mitigating storm water runoff.

Urban tree as runoff mitigation

The canopies of urban trees play a crucial role in significantly diminishing surface runoff within cities, thereby mitigating the risk of flooding and preserving essential ecosystem services for countless urban residents. Surface runoff emerges when precipitation or melting snow traverses impervious surfaces like roads, sidewalks, or rooftops. This phenomenon results in the depletion of water volume and an accelerated flow rate, causing soil erosion and transporting pollutants into surface water bodies. Furthermore, an excess of runoff has the potential to overwhelm urban drainage systems, precipitating extensive flooding in city areas (William R. Selbig, 2021).

Urban trees play a multifaceted role in minimizing surface runoff through the interception of rainfall, influencing the evaporation and infiltration of retained water, enhancing air quality, decreasing atmospheric CO_2 levels, and contributing to energy consumption reduction. One frequently discussed benefit of urban trees is their capacity to reduce surface runoff. In a study conducted by (D. Armsona, 2013) in Manchester, UK, runoff from three different plots covered with grass, asphalt, and equipped with tree pits was measured. The findings revealed that trees can decrease the runoff coefficient from asphalt surfaces by 38% in summer and 43% in winter. Similarly, research by (Qingfu Xiao, 2011) in Davis, Canada, demonstrated that the strategic arrangement of trees and engineered soil on a parking lot led to an 89% reduction in runoff. Rainfall interception measurements under two deciduous tree species in North Vancouver, Canada, indicated that urban trees canopy can intercept an average of 50-60% of rainfall, thereby reducing runoff. Study conducted by (S.J. Livesley, 2014) in Melbourne, Australia, during the fall, observing runoff reduction ranging from 30 to 45%, depending on canopy density. Even in residential yards, where urban forests are common, a case study in North Carolina, USA, reported a runoff reduction of 9–21%. Simulation using the UFORE-Hydro model in Baltimore, USA, illustrated that introducing trees to 12% of impermeable areas could result in a 3% reduction in runoff. The SCSCN method, frequently employed for runoff reduction modeling, indicated a 1–5% reduction in a Swedish study. Moreover, Huang et al. integrated various components of existing models, presenting an approach for estimating the efficiency of trees in reducing urban runoff (Katarina Zabret, 2019).

The recorded data on rainfall partitioning served as the basis for estimating the reduction in surface runoff resulting from the planting of selected tree species in the city of Ljubljana, Slovenia. Surface runoff calculations were conducted for a parking lot under two scenarios: one without trees and the other with trees, taking into account variations in seasonal characteristics (leafed and leafless), as well as dry and wet years, using values for gross rainfall and interception. In the wet season, the total runoff from the vegetation-free parking lot amounted to 18,521 m3 of stormwater, and in the dry season, it reached 10,949 m3. Introducing pine trees (covering 10% of the area) led to a yearly runoff reduction of 7.3%, while birch trees resulted in a reduction of 4.8%. Both birch and pine trees exhibited greater runoff reduction during the leafed period compared to the leafless period and in wet years compared to dry ones (Mojca Sraj, 2019). In Ohio's urban forest, trees reduced storm runoff by 7%. In Munich, Germany, extending tree coverage by an additional 19% was estimated to reduce runoff by 2%, and highly forested areas near Baltimore were projected to achieve a runoff reduction of 26%. Lei Yaoa, 2015, estimated that adding 11% tree canopy area to the green spaces in central Beijing would enhance runoff retention by 30%. Simulations by (Q.

Xiao, 2002) indicated that 29,299 street and park trees in Santa Monica, CA, could annually intercept 1.6% of rainfall, resulting in a decrease in storm water treatment and flood control costs by $110,890.

Methodology

Study Area Description

Hawasa is located in the Sidama Region of Ethiopia. Geographic coordinates of latitude, North 7^o 3' 0″ and 6′ 45″, and longitude, East, 38^o 28′ 0'', at an elevation of 1,775 meters (5,823 feet) and lies 333 kilometers (207 mi) to the south-west of Addis Ababa. Hawassa is administratively segmented into 8 sub-cities and 32 Kebeles, encompassing a total administrative land area of 15,720 hectares within its municipal boundary

Hawasa city is located on the shores of Lake Hawassa in the Great Rift Valley. Lake Awassa is about 15 km long and 5.5 wide, with a maximum and mean depth of 21 m and 10 m, respectively, situated at the centre of a collapsed large caldera, at an altitude of 1680 m above mean sea level (m a.s.l.) (NUPI 1994). The catchment of Lake Hawassa is formed of Pliocene-age volcanic rock. Significant faults and ground cracks in the rock result in a highly permeable soil and unconfined aquifers in the area. The distance to the static groundwater level fluctuates, ranging from a shallow depth of a few meters in low-lying regions to as deep as 40 meters in elevated areas (Ayenew and Tilahun, 2008)

Climate of Hawasa has a mean annual rainfall of about 950 mm and temperature of 20°C. Typically, the primary rainy season periods start from June to October.

The Ethiopian Central Statistical Agency estimates that the population of Hawasa is 351,469 and it has an annual population growth rate of 4% (CSA, 2015). The population is relatively young, with 65% under 25 years of age and around 5.5% over 50 years of age.

.

Location Map

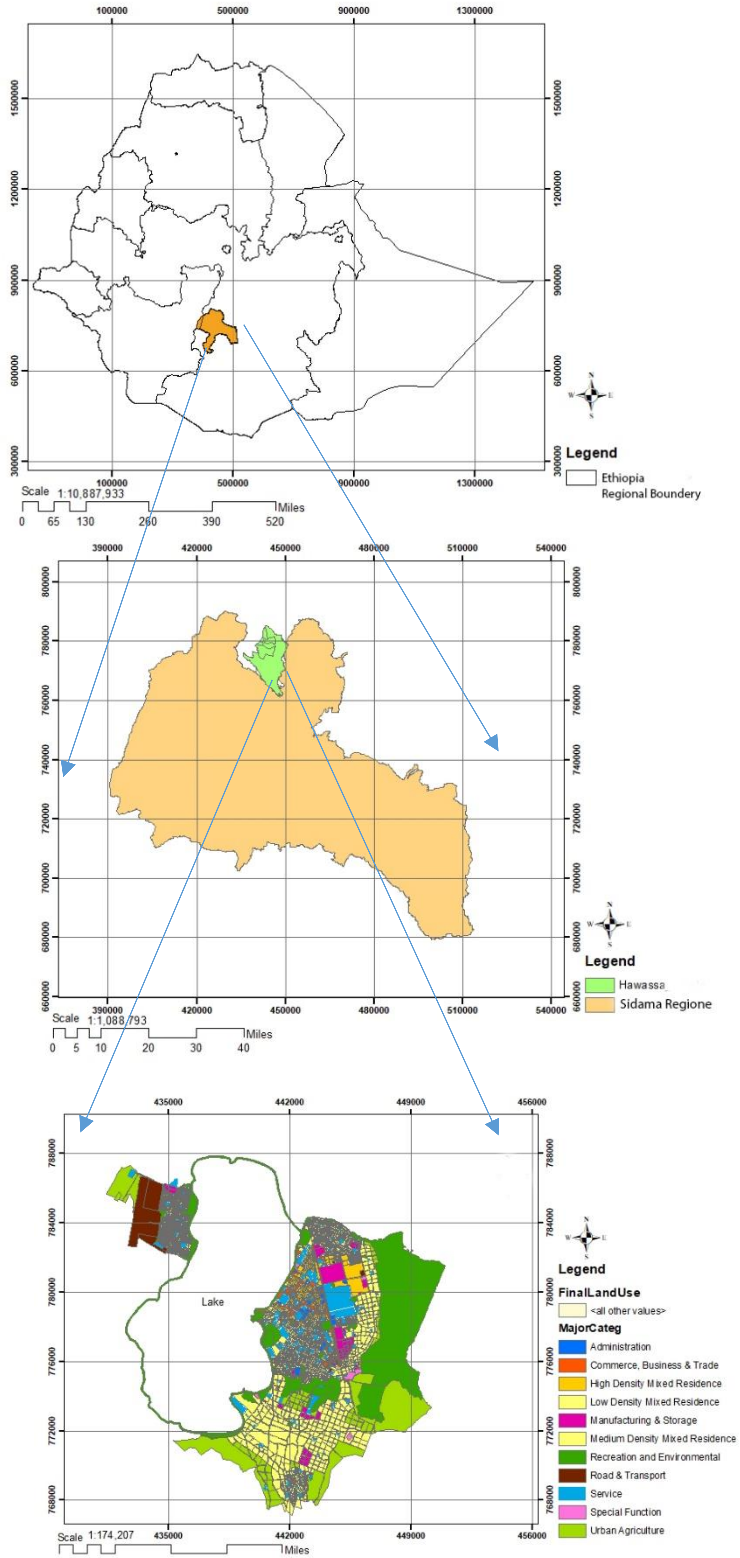


Figure 5: Locational Map of Hawasa City Administration (2007 E.C)

Method of Data Collection

Type and Data source

The data used for the research was based on the Land use map of the Hawasa city provided by Hawasa city Administration. Based on the land use map ground measurement and observation was made to identify the trees in deferent part of the city by preparing Base Map. The following steps was made to collect data from the ground':

1. High-resolution satellite imagery or aerial photographs of Hawasa city(USGS/Landsat8).

2. Geographical Information System (GIS) software such as ArcGIS.

3. Computer with suitable processing capabilities.

4. Digital image analysis software such as Google Earth Engine.

5. Field equipment (optional) for ground-truthing and validation purposes such as GPS device, measuring tape, and camera.

Data Analiysis:

The analysis of tree canopy cover in Hawasa city was conducted using the i-Tree canopy software and USGS-Landsa8. A component of the i-Tree tool developed by the United States Forest Service in 2006. This web-based tool, available for free access, generates quantified and statistically valid values for canopy cover.

The sampling procedure followed four major steps:

5. defining of the study area boundary by importing boundary shapefile of the Hawassa city into the i-Tree canopy,
6. predefinition of the land surface cover types to be surveyed
7. Classification of each random point overlapped on the aerial image that shows the land surface cover types categorized as Tree, impervious surface shrub and bare land. The defined area for this study includes the urbanized part of the Hawasa city

8. The land surface cover of the study area was quantified using a random point sampling procedure. Sample points were randomly distributed by the i-Tree software onto the 2023 Google Map image, and the materials that covered the ground were classified by interpreting the coverage types within the Hawasa city
   A total of 503 random sample points were repeatedly added and classified

i-Tree Landscape

Another way to measure tree canopy is through the i-Tree Landscape tool. This tool uses land cover data from the National Land Cover Database. Once a location is selected, an estimate of the amount of tree canopy is provided. You can also explore location data (census data, forest risk, future climate, etc.), see tree benefits, prioritize tree plantings, and generate reports. This is a great, free tool from i-Tree with lots of information to explore.

Point Sampling

The simplest method is to use a point sampling technique developed by the i-Tree Canopy tool. Random points, like those shown in the map, are generated within an area and manually assigned a value of “tree” or “non-tree” until a 1-2% standard error is reached. By dividing the number of "tree" points by the total number of points, you can quickly get an estimate of the percent canopy cover or any other land cover type.

High Resolution Land Cover Mapping(landsat8)

The third method uses (GIS) remote sensing technology and high-resolution imagery (aerial or satellite). These data inform all other aspects of the project by categorizing a given landscape into specific classes such as tree canopy, other non-canopy vegetation, impervious or hardscape, bare soil, or water. With this information in hand, you can then look at the quantity and geographic distribution of each type of land cover and ask many questions like:

- Where is there existing tree canopy? How much?
- How much gray infrastructure (roads, buildings, parking lots, etc.) is there compared to green infrastructure (trees, grass, and other vegetation)?

Storm water and canopy assessment

According to the Hawasa city tree canopy analysis, the study found that the Total percentage of the water cover is 20.08%. the study was done compering the water bodies with other land cover (Table2), such as Impervious Surface (built up landscape)35.39%,Grass/Herbaceous 11.73%,Shrubs 8.35%, Bare Ground 6.36% and Water 20.08% of the Hawasa city. This data give consideration for the balanced distribution of the Existing Land Cover. For example, the Bare ground which account 6.36% cover 9.99 Sq.Km area of the Hawasa city give Additional room for future planting of additional trees in situation there is need for planting the tree to meet the desire goal by Hawasa city Administration.

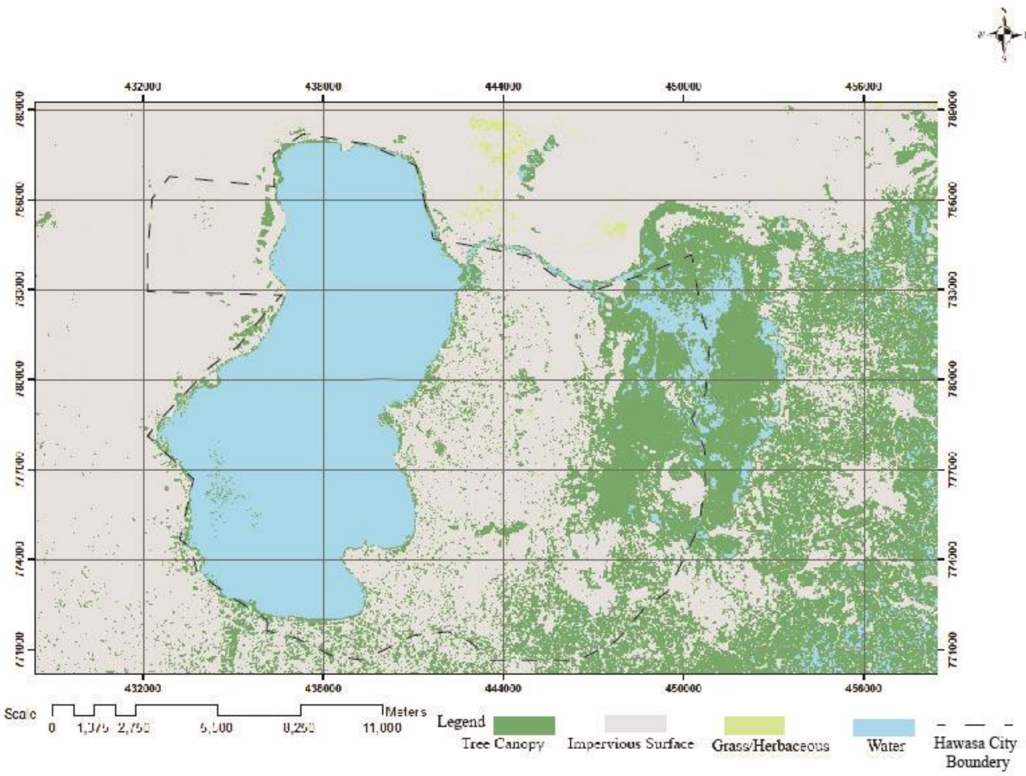


Figure 7: Tree Canopy Cover Assessment Map of Hawasa city.

Abbr.	Cover Class	Points	% Cover ± SE	Area (mi²) ± SE
H	Grass/Herbaceous	59	11.73 ± 1.43	4.00 ± 0.37
IO	Impervious Other	0	0.00 ± 0.00	0.00 ± 0.00
IS	Impervious Surface	178	35.39 ± 2.13	10.04 ± 0.54
S	Shrubs	42	8.35 ± 1.23	5.13 ± 0.32
S	Soil/Bare Ground	32	6.36 ± 1.09	3.63 ± 0.28
T	Tree	91	18.09 ± 1.72	9.62 ± 0.44
W	Water	101	20.08 ± 1.79	5.13 ± 0.46
Total		**503**	**100**	37.55

Table 1: Land Cover class of Hawasa City (Data analyzed Using iTree)

The total area of the Hawasa city is 157.2 Sq.Km, from this total area, 97.25 Sq.Km was analysed under i-Tree using Random sampling method. From the total area analyzed 24.90 Sq.Km area is covered by Tree this account for 18.09% of the total Canopy coverage of the Hawasa city.

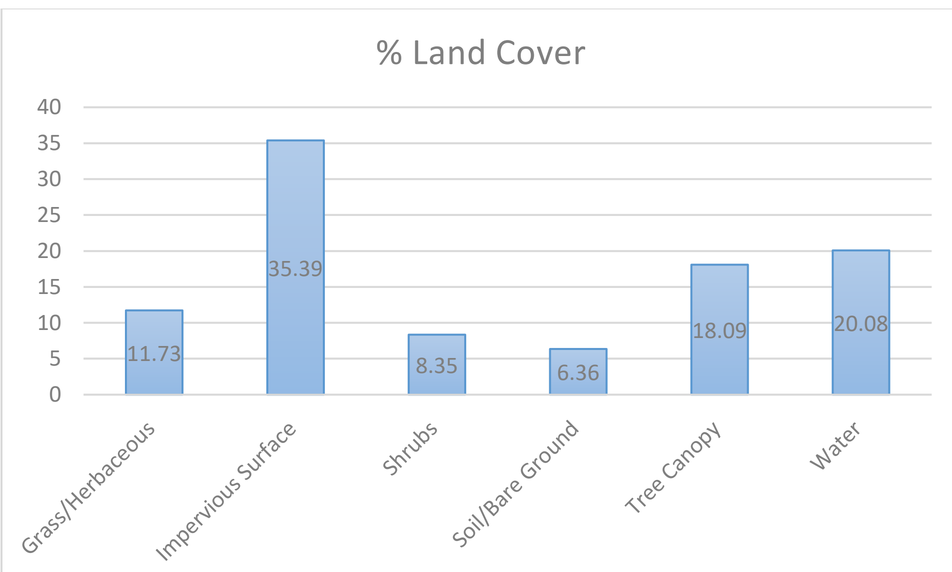


Figure 8: Tree Canopy and Land Cover Data Summery of Hawasa city

Tree Benefit Estimates: Hydrological

Abbr.	Benefit	Amount (Kgal)	±SE	Value (USD)	±SE
AVRO	Avoided Runoff	35.82	±2.66	$320	±24
E	Evaporation	804.35	±59.82	N/A	N/A
I	Interception	809.58	±60.21	N/A	N/A
T	Transpiration	761.65	±56.64	N/A	N/A
PE	Potential Evaporation	5,172.93	±384.70	N/A	N/A
PET	Potential Evapotranspiration	4,266.33	±317.28	N/A	N/A

Table 2: Tree Hydrological Benefit Estimates for Hawasa city (Data analyzed Using iTree).

Trees play a vital role in the urban hydrological cycle. They can intercept rainfall, reduce storm water runoff, and contribute to groundwater recharge. The figure in Table5 indicates the capacity of the existing tree canopy cover of Hawasa city to intercept 809.58 gall/mil^2/yr and avoide runoff by 35.82kgall/mil^2/year, helping to mitigate the impact of storm water runoff on urban areas.

It is important to note that the benefits can vary based on factors such as tree species, canopy density, soil type, and local climate conditions. The i-Tree tools use scientific models and data to provide these estimates and help urban planners make informed decisions about managing and preserving urban forests for their ecological and societal benefits.

According to the analysis in Table2, we have 18.09% of canopy cover in Hawasa city, it can provide several benefits for carbon sequestration and reducing storm water, including: Carbon storage of 543.53 KT from Table3: Trees absorb carbon dioxide from the atmosphere and store it in their biomass and in the soil. Having a high percentage of canopy cover in an urban area can increase the amount of carbon stored, helping to mitigate the effects of climate change and save energy cost of $25,281,893.

Carbon dioxide (CO_2) sequestration of 21.63KT in Table3: Trees also sequester carbon by converting it into organic matter through photosynthesis by removing 2.44Tone of carbon monoxide annual per mile squere(Table4). This process helps to remove carbon dioxide from the atmosphere, store it in the tree's biomass, and save as energy cost of $1,006,695(Table3).

Improved air quality: Trees absorb pollutants such as carbon dioxide, nitrogen dioxide, and particulate matter, improving air quality in urban areas. This can help to reduce the amount of carbon emissions from transportation and other sources, According to Table4 Total of 161.73Tone emission utilized by 18.09% of canopy cover in Hawasa city end up saving $1,033,185.

Reduced storm water runoff of 135,590 liter from Table5**:** Trees help to absorb and filter rainwater, reducing the amount of storm water runoff and the risk of flooding. This can help to protect the city's infrastructure and reduce the risk of property damage and saving $320 in Kgal/mi^2/yr. The estimated benefits of the existing tree canopy coverage of Hawasa city avoid runoff of 35.82 Kgal/mi^2/yr (in Table5).

Overall, having 18.09(Table2) percent of canopy cover in Hawasa city, Ethiopia can provide significant benefits for carbon sequestration and storage, helping to mitigate the effects of climate change and improve the overall health and well-being of the city's residents..

Rainfall Interception by Trees

The volume of water that intercepted by tree during rain is calculated as follow:

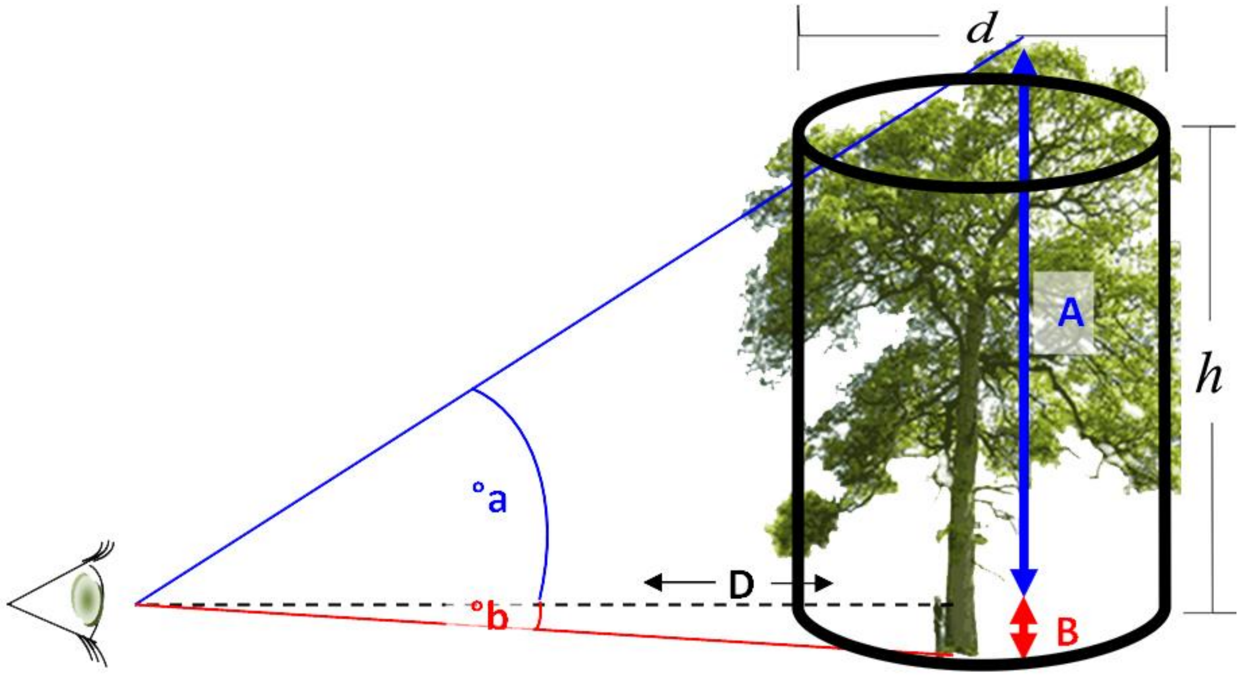


Figure R1: Rainfall interception Diagram

RF = $\pi r^2 h/1$……………………………………………………………………equation 5

The experiment conducted by pouring water at the top of tree (Granville rebosta) full-grown tree and record the time for the water to reach the ground and reach the maximum infiltration rate of the soil.

Grevillea robusta: Silk oak, *(Grevillea robusta)*

Serving Size: 3m diameter

Height: 12m

Condition: Excellent

Rainfall Intancity (RFI) = p/t = where p is Rainfall debth and t is duration of rain occurred. The intensity of rain for Hawasa city is 965.2 mm, taking the total area of the tree canopy to calculate the intercepted rainfall.

RFI: 965.2 mm = 0.9652m

Intercepted RF = RFI X Area of the single tree canopy

In area of 3 x 12m one tree canopy *(Grevillea robusta)* can intercept rain up to 34,740 L/yr therefor the intercepted rain of total city of Hawasa can be calculated:

Intercepted RF = RFI X Area for a single tree *Canopy* to intercept………equation

Impervious (Paved surface and Built up) is the major Couse of runoff water in Hawasa city. The percentage cover of impervious surface in the Hawasa city is 35.39% (Table-2) of the total area of Hawasa city which is 55.63 Sq.Km. The total runoff that emerged from this impervious area will be 53,694,076m^3 (53,694,076,000L). Using this result, we can calculate the number of tree needed to reduce this runoff in Hawasa city. The interception of rain by tree depend on the density and structure (serving size) of tree. According to the result in table-6 the study uses twelve(12) tree species to intercept rain depending on their intercepting capacity. Now divided the total runoff of the Hawasa city by 12 tree species from table-6 to assign each species depending on their interception capacity, which is 4,474,506,333L of runoff assign to each 12 species to be mitigated. Then divide this result by rainfall interception value of each tree separately from table-6. The result shows Around one million trees composed of those 12 tree species needed to mitigate the total runoff of 53,694,076,000L. In this case, the study take the density of each tree species identical.

Discussion

Tree canopy cover in Hawasa city intercepts rainfall and mitigate storm water. The interception process depends on various factors, including the density and structure of the tree canopy, leaf shape and size, and precipitation characteristics. For Instance, In area of 3 x 12m one tree canopy *(Grevillea robusta)* can intercept rain up to 34,740 L/yr(Table-6) therefor the intercepted rain of total city of Hawasa can be calculated by multiplying rainfall Intensity with Area of a single tree *Canopy* to intercept the rainfall. A denser canopy with larger leaves will generally intercept more rainfall compared to a sparse or less leafy canopy. Additionally, the intensity and duration of rainfall events also affect how much rainfall is intercepted. Interception serves several important functions. It helps regulate the amount and timing of water that reaches the soil, reducing both erosion and surface runoff. By temporarily storing and evaporating rainfall, tree canopies also contribute to the local water cycle and help moderate temperature and humidity levels in the immediate vicinity. According to our study result around one million trees composed of twelve

(12) tree species (Table-6) needed to mitigate the total storm water of 53,694,076,000L (Table-2) that created on paved surface which account for 35.39% (55.63 Sq.Km)of Hawasa city land area.

Conclusion and Findings

The canopy cover assessment of Hawasa City indicates that there is significant room for improvement in the area. Although some sections have greater canopy coverage, large areas are unplanted and lack sufficient protection from environmental stressors. In order to create a healthier and more resilient environment, it is important to strategically plan for the planting of trees in both public and private spaces throughout the city. This will serve to reduce air pollution, improve water quality, reduce runoff, increase biodiversity, and create cooler temperatures in urban areas. Coordinating efforts among local authorities and citizens can ensure that planted trees thrive for future generations within Hawasa City.

Hawasa city landscape composes of different land cover from the total land of the city 35.39% is impervious surface, 18% tree cover, 20% water bodies, 8.35% shrubs, 6.36% bare land, 11.73% grass cover.

Total canopy cover is 18.09% as a result around 565,160 Ton of carbon is stored and sequestered from atmosphere and saved around \$27,321,773 in mi^2/yr for energy cost for cooling indoor. As well as 135,590 lit of storm water runoff reduced, avoids property damage, and save \$320 mi^2/yr. In the area of $1m^2$ of the land 615.18 W of Heat energy that come from sun will be reflected back to the atmosphere and only 307.59W of energy will be absorb by light leave tree.
18% canopy will cover 46,409,220 m2 of Hawasa city area therefor multiply by 615.18W it give as the total reflected radiation of 28,550,023,959.6 W(28,550 Megawatt) which transform/1in to heat energy on the surface of the earth.

Acknowledgements

The authors would like to thank Wondwosen Debebe (PhD candidate) for suggesting the idea for this paper

References

Akbari, H. (2019, january 18). Global Cooling: Increasing World-Wide Urban Albedos to Offset CO2.

Arideep Mukherjee, M. A. (2018, January 17). Use of GLM approach to assess the responses of tropical trees to urban air pollution in relation to leaf functional traits and tree characteristics.

Blaz Klobucar, Neil Sang, Thomas B. Randrup. (2021, june 8). Comparing ground and remotely sensed measurements of urban tree canopy in private residential property. doi:10.1016/j.tfp.2021.100114

Britta Jänicke, F. M.-T. (2014, December 19). Evaluating the effects of façade Bioclimate in a Complex Urban Environment.

City of Seattle office of Sustanability. (2021). City of Seattle Tree Canopy Assessment.

D. Armsona, P. S. (2013). The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. doi:doi.org/10.1016/j.ufug.2013.04.001

David J. Nowak, D. E. (2006, April 4). Air pollution removal by urban trees and shrubs in the United States.

Dobos, E. (2005, December). Albedo. doi:10.1201/NOE0849338304.ch15

Dr. James R. Fazio. (2016). Understanding Tree Canopy Assessments.

E. Gregory McPherson a, J. R. (2011, January 30). Million trees Los Angeles canopy cover and benefit assessment. pp. Pages 40-50. doi:10.1016/j.landurbplan.2010.08.011

Eleftheria Alexandri, P. J. (2007, September 21). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. doi:doi.org/10.1016/j.buildenv.2006.10.055

Elena Morini, A. G. (2016, October 7). The Impact of Albedo Increase to Mitigate the Urban Heat Island in Terni (Italy) Using the WRF Model.

Mefekir Woldegebriel Tessema, B. G. (2023, November 6). Quantification of land use/land Quantification of land use/land cover dynamics and urban growth in rapidly urbanized countries: The case Hawassa city, Ethiopia. doi:0.1080/21650020.2023.2281989

Monika Ziemiańska, R. K. (2017, August). BIOMETRICS OF TREE-RING WIDTHS OF (POPULUS XCANADENSIS MOENCH) AND THEIR DEPENDENCE ONPRECIPITATION AND AIR TEMPERATURE IN SOUTH-WESTERN POLAND.

Negash, L. (2021). .A Selection of African Native Trees: Biology, Uses, Propagation and Restoration Techniques.

Nuruzzaman, M. (2015, March). Urban Heat Island: Causes, Effects and Mitigation Measures -A Review. doi:10.11648/j.ijema.20150302.15

Q. Xiao, E. G. (2002). Urban Ecosystem.

Teresa Zölcha, J. M. (2016, October 3). Urban Forestry & Urban Greening Using green infrastructure for of heat mitigation measures at the micro-scale. doi:dx.doi.org/10.1016/j.ufug.2016.09.011

Tikabo Gebreyesus, K. Y. (2022, july 18). Study on the land surface cover dynamics of built-up areas and its implication for sustainable urban planning in Hawassa city, Ethiopia. *GeoJourna*. doi:10.1007/s10708-022-10729-x

Tousheng Huang, H. Z. (2019, July 4). Theoretical Study on Self-Organization of Vegetation Patterns Triggered by Water Resource in Deposited Sediment Layer.

U.S. Department of Agriculture. (2019). *URBAN TREE CANOPY ASSESSMENT:A Community's Path to Understanding and Managing the Urban Forest.*

W. L. CHAMEIDES, F. F. (1992, April 20). Ozone Precursor Relationships in the Ambient Atmosphere.

Wen-Ching Chuang, C. G. (2017, june 15). Tree canopy change and neighborhood stability: A comparative analysis of Washington, D.C. and Baltimore, MD. doi:10.1016/j.ufug.2017.03.030

William R. Selbig, S. P. (2021, October 28). Quantifying the stormwater runoff volume reduction benefits of urban street tree canopy.

Xie, J. T. (2022). Bending the Pollution Curve: An Analysis and Prioritization of Pollution Management in Ethiopia.

Yang Xinga, P. B. (2019, July 22). Tree distribution, morphology and modelled air pollution in urban parks of Hong Kong.

YODA, K. (1974). THREE-DIMENSIONAL DISTRIBUTION OF LIGHT INTENSITY IN A TROPICAL RAIN FOREST OF WEST MALAYSIA. doi:doi.org/10.18960/seitai.24.4_247

Work plan

No	/1 /1Task	/1 /1Time cost: Week											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Literature review												
2	Contextual review												
3	Data collection												
4	Data analysis												
5	Drawing findings												
6	Conclusion												
7	Recommendation												
8	Report writing												