**Identifying Supply and Demands of Ecosystem Services from Urban Street Trees, and Design Through Nature-Based Solutions for Long-Term Provision of Ecosystem Service in Hawassa City, Ethiopia**

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A Thesis submitted to the Graduate Program of Ethiopian Institute of Architecture, Building Construction, and City Development(EiABC), Addis Ababa University in fulfillment of the Requirements for the Degree of Master of Science in Landscape Architecture at Addis Ababa University.

Addis Ababa,Ethiopia

June 2024

## CERTIFICATION

This thesis is submitted to the graduate Program of the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), in partial fulfillment of the requirements for the Master of Science Degree in Landscape Architecture.

Title of thesis: ***Identifying supply and demands of ecosystem services from urban street trees, and design through a nature-based solution for Long-term provision of ecosystem service.in Hawassa city, Ethiopia*.**

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## DECLARATION AND CONFIRMATION

Declaration

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the Institute.

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Confirmation

The thesis can be submitted with my approval as an Institute's advisor. Advisor's Name: Prof.Kumelachew Yeshitela

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**ABSTRACT**

*Urban trees offer a variety of advantages due to the variety of tasks they carry out. They are an important component of urban and suburban areas and can change the way streets look and offer a variety of ecosystem service (regulating, provisioning, supporting, and cultural) benefits. However, urban trees are highly influenced by people and other factors that can negatively affect ecosystem service provision. When street trees are planted in Hawassa, ecosystem service is not taken into account; instead, the emphasis is placed on aesthetics, shade, and quickly growing plants rather than user demand and the ecosystem service provision by the street tree that led to ecosystem service supply and demand imbalance. This study was conducted on five different streets in Hawassa city and ecosystem services examined in the study are local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place. The objectives of the study are assessing the existing street tree species type and street scape element, identifying challenge of street tree development and management, and identifying the supply and demands of ecosystem service provision from urban street trees. During the study, 1588 mature trees, representing 37 species, 22 families, and 665 sapling trees, representing 13 species and 11 families have been identified. The study was conducted by collecting data from street user and officials who have direct involvement in urban planning managing and developing the street and by conducting observations on the selected streets. In analyzing the data descriptive statistic for the questionnaire filled by street user and simple qualitative analysis are used for information from key informant interview and observation made on the street. Results indicated that the availability of street scape elements are rated from very poor to medium. Likewise, it also indicated that there is a lack of street scape element along the street and the study also highlight several challenges associated with street trees, lastly, most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, storm water management, and sense of place indicates that there is a significant gap between the provision of and demand for ecosystem services provided by street trees in urban areas. In general, the study forwards a recommendation for enhancing the current status of street tree and for future development and forwards new possible design prototypes that considers street scape element in relation street tree to maximize the value of ecosystem provision.*

***Keywords***: Urban street tree, Ecosystem service, Ecosystem supply, Ecosystem Demand , streetscape element

## ACKNOWLEDGMENT

First and foremost, I would like to praise Allah the Almighty, the Most Gracious, and the Most Merciful for His blessing in the completion of this thesis.

I would like to express my heartfelt appreciation and deep gratitude to my thesis advisor, Prof. Kumelachew Yeshitela, for his invaluable guidance, inspiration, and unwavering support throughout my research journey.

I would also like to express my sincere thanks to the experts in the field of city beautification and urban infrastructure development of Hawassa, particularly Mr. Teklu and Mr. Mengestu, for their time, expertise, and valuable contributions.

Finally, I cannot overlook the immense support and inspiration I have received from my dear family and friends. Their unwavering belief in me, constant encouragement, and unconditional support has been my pillars of strength throughout this journey. I am truly grateful for their presence in my life and for being a constant source of motivation.

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# List of Acronyms

| | |
|---|---|
| ES | Ecosystem service |
| ESC | Ecosystem services cascade |
| GI | Green infrastructure |
| GHG | Greenhouse gas |
| LS | Local Street |
| NBS | Nature based solution |
| PAS | Principal Arterial Street |
| SAS | Sub Arterial Street |
| UGI | Urban Green Infrastructure |

# Chapter one: Introduction

## 1.1. Background of the Study

The world is urbanizing at an unprecedented rate, with the United Nations predicting that 68% of the world's population projected to live in urban areas by 2050 (United Nations,2018). Although urbanization has brought great benefits to humanity, it has also had negative effects on the environment and the ecosystem service it provides (Seto et al.,2011)

Africa is currently experiencing a rapid urbanization process, resulting in cities lacking the qualitative elements that create an attractive built environment, provide public amenities, and enable a satisfying urban lifestyle. At the same time, the quality of the public space is poor (United Nations Habitat III, 2014).

Urbanization has progressed significantly in Ethiopia in recent years, and various challenges have a risen in the urban environment. As urbanization expands, there is often a loss of green spaces and natural habitats, which also leads to a decrease in biodiversity (Mekonnen et al., 2018), without a properly planned environment, these spaces are causing environmental problems such as rising temperatures, air and water pollution, and greenhouse gas emissions (Molla et al.,2019).

Hawassa city is one of the fastest growing urban centers in Ethiopia and its economic growth and developmental activities such as building, road construction, private residence expansion and many other anthropogenic activities have been on steadily increasing (Birhanu et al., 2020).Consequently, the vegetation of the area has been under enormous human impact and may be on the decline, moreover the expansion of urban areas can lead to the urban heat island effect, where cities experience higher temperatures compared to surrounding rural areas (Tulu et al., 2020). this impacts on the environment.

This rapid urban development needs to be complemented by urban green infrastructure (UGI) to address the environmental challenges that cities will face due to rapid urbanization. Properly planned and developed green areas are an essential part of UGI that effectively reduces the undesirable environmental impacts of urban areas(Baró et al., 2015). In urban areas, green infrastructure (GI) elements may include parks, urban forests, allotments, street trees, green roofs, etc. (Landscape Institute,2009) and street greenery is also an important part of the UGI (Zhang and Dong, 2018).

UGI provides services to people, collectively referred to as ecosystem services (ES). ES are the benefits people obtain from ecosystems upon which human well-being largely depends (Millennium Ecosystem Assessment 2005). There are a variety of services that generally fall into four categories: Regulatory Services (e.g., pollination, climate regulation, air quality regulation, and water purification), Supply Services (e.g., food production, biomass, freshwater, mineral resources), Support services (e.g., nutrient cycling, primary production, soil formation) and cultural services (e.g., recreation, aesthetic landscapes, cultural heritage) (Zhao et al.,2015). The benefits of ecosystem services come with the upfront capital cost and (minimal) maintenance of natural solutions, such as planting trees.

Trees provide many services to the environment and demonstrate how one natural component can provide multiple environmental and social services. One of the key services they can provide shade and reduce the urban heat island effect. By forming shadows and lowering surface temperatures, they help create more comfortable microclimates and reduce the need for excessive air conditioning, resulting in energy savings and reduced greenhouse gas emissions (Escobedo et al.,2019).

Street trees also contribute to improve air quality by filtering pollutants. They absorb harmful gases and particulate matter such a as nitrogen dioxide and ozone, reducing air pollution and promoting healthier urban environments (Nowak et al.,2013; Kumar et al.,2018). In addition, street trees play a crucial role in managing storm water runoff. Their canopies intercept rainfall, slowing down the rate and volume of runoff, Which helps prevent flooding and overloading of storm water system(Yang et al., 2020).

The roots and soil of street act as natural filters, absorbing and retaining water, which improves water quality and helps groundwater recharge. Street trees Provide valuable habitat for urban wildlife, supporting biodiversity in cities. They provide food sources, nesting sites, and shelter for birds, insects, and small mammals, contributing to the conservation of native species and ecological balance (McDonnell et al.,2009).

Furthermore, street trees enhance the aesthetic appearance of cities and serve as places of relaxation for residents. Their presence improve the visual quality of streetscapes, making neighborhoods more attractive. people can engage in activities such as walking, jogging, and enjoying nature, which positively impacts mental and physical well-being (Nowak et al., 2013)

In the past, street trees have been essentially perceived as decorative elements (Sanesi and Chiarello, 2006), but nowadays their environmental, economic, social, and aesthetical services and ecosystem service provision have been increasingly acknowledged

(Millennium Ecosystem Assessment, 2005; Seamans, 2013). Human well-being is affected by gaps between ecosystem service supply and demand (Reid, et al.,2005).

## 1.2. Statement of the Problem

Urban street trees play a crucial role in the development and maintenance of public green infrastructure in urban areas. Urban street trees are an important component of urban and suburban that can change the way streets look and provide a range of ecosystem services that contribute to the well-being of both humans and the environment.

Unfortunately, urban trees are subject to various factors that can lead to imbalances between the supply and demand of ecosystem services. These factors include human activities such as the presence of vehicles, buildings, pavements, utility lines, underground pipes, and animals, which can contribute to environmental issues (Birhanu et al.,2020). Poor selection of tree species that are not well-suited to the local environment, including climate and soil conditions, can lead to reduced ecosystem service provision (Liang and Huang.,2023).

The gaps between the supply of ecosystem services and human demand can arise due to various factors, including land use changes, ecosystem degradation, climate change, and population growth (Yao et al., 2022), Rapid urbanization and limited space in urban areas can restrict the planting and growth of street trees, reducing their capacity to provide ecosystem services (Nowak et al., 2013).

Specifically, when planting street trees in Hawassa, the focus is often primarily on aesthetics, shade, and growth rate, rather than considering user demand and the provision of ecosystem services by the trees. This approach neglects the crucial role that street trees play in addressing environmental challenges and meeting the needs of users. Additionally, the poor urban tree management in Hawassa city has resulted in increased stormwater runoff due to inadequate tree planting and maintenance practices, leading to frequent flooding during the rainy season and causing property damage and public safety concerns. Furthermore, uncontrolled growth of tree roots has damaged underground utilities such as water pipes and sewer lines, resulting in costly repairs and service disruptions.

Studies have highlighted that street trees are often selected for their visual appeal and fast growth, with ecosystem services being secondary considerations (Kirkpatrick et al., 2012; Conway et al., 2016). In addition, there is a knowledge gap regarding street trees and their role in providing ecosystem services. There is a clear lack of studies in sub Saharan Africa on exploring how to provide optimized use of trees tuned to the local natural conditions, socio-cultural context, and governance structures (Tan et al.,2017; DuToit et al. 2018).In order to generate actionable knowledge for urban tree planting, a comprehensive understanding of the association among species, traits, and ecosystem services is needed (Liang and Huang., 2023).

Humans consume many services and products provided by ecosystems to satisfy and enhance their well-being(Zhai *et al.*, 2021). The review by Du Toit et al. (2018) on urban green infrastructure and ecosystem services in Sub-Saharan Africa showed that there is a limited number of studies carried out. Urban nature-based solutions have proven to be a potent tool for addressing many of the most pressing urban environmental issues by taking advantage of the ecosystem services provided by nature to deliver specific, measurable human benefits (Escobedo *et al.*, 2011).

The Street tree supply and demand must be determined to establish what services we may reasonably expect from already providing, to get long-term ecosystem services provision from street tree based on the demand of the users.

## 1.3 Objective of the Study

### 1.3.1 General Objective

To assess the supply and demand of ecosystem services from urban street trees in Hawassa and propose nature-based solutions to address gaps.

### 1.3.2 Specific Objectives

Conducting this research proposal under the above-generalized objective has the following specific objectives:

- To list the existing street tree species and streetscape elements in Hawassa.
- To assess the challenges of street tree development and management in Hawassa.
- To identify the supply and demands of ecosystem service provision from urban street trees in Hawassa.
- Propose specific GI designs to provide the least in supply or most in demand ecosystem services for use in future roadside plantings.

## 1.4 Research Questions

To achieve its objectives, the study will be directed towards finding answers to the following three research questions:

- What are the existing street tree species and streetscape elements are present in Hawassa?

- What are the challenges in the development and management street trees in Hawassa?
- What are supply and demands of ecosystem service provision from urban street trees in Hawassa?

## 1.5 Scope of the Study

### 1.5.1 Thematic Scope

The scope of this study is to identify the supply and demand that street user gained from street trees to improve the performance of urban street trees in delivering needed ecosystem services.

### 1.5.2 Spatial Scope

The spatial scope of the study consists of two elements:

**Geographically**, the study was limited to street trees within the geographic city of Hawassa. Hawass has been chosen as the geographic focus for street trees with ecosystem service due to its unique environmental context and its significance in the urban development goals. As a rapidly urbanizing city and regional economic hub, Hawassa faces challenges related to population growth and environmental sustainability. The city's climate, topography, and existing green spaces make it an ideal candidate for street tree planning with a focus on ecosystem services.

## 1.6 Significance of the study

The significance of this study is its potential to inform the Green Development office in assessing the current supply and demand for street trees, aiming to enhance future demand for ecosystem services associated with beautification and green development. Although not exhaustive in addressing all aspects of identifying ecosystem service demands from urban street trees, this study can inspire future researchers interested in this field to conduct further studies. Understanding the enduring ecological and social impacts of street trees in diverse urban settings is crucial for guiding sustainable urban planning and design. Moreover, advancing innovative techniques and technologies to promote the growth and resilience of street trees in paved urban environments is a vital research direction. The study's findings could serve as a reference point for regional governments and policymakers, including urban planners, to establish connections between street trees and ecosystem services. Ultimately, this study has the potential to prompt a reevaluation of urban street tree planning that integrates ecosystem services into future developments, ultimately contributing to a healthier, more attractive, and more sustainable urban environment for all street users.

## 1.7 Research limitations

During this study, the researcher faced few challenges such as difficulties in obtaining secondary data and maps and the number of professionals related with the issue being studied was the main challenge.

# Chapter two: Literature Review

## 2.1 Introduction

The literature review presented in this chapter discussed the relevant literature on street trees and their ecosystems. This review begins by defining some key terms and concepts related to the topic, and then discusses the benefits of street trees based on ecosystem services.

### 2.1.1 Definitions of key terms and concepts

It is proper to start this definition of key terms and concepts by first defining the fundamental term of Street itself(Reid, 2005). Contributions of ecosystem structure and function in combination with other inputs to human well-being(Müller and Burkhard, 2012).

Street

In a built environment, a street is a public route. It is a publicly accessible area of land that is adjacent to buildings in an urban setting and where people are free to congregate, engage, and move around. People primarily experience the livability of cities on their streets. One of the less often used public areas in cities is the street. Streets are dynamic spaces that adapt over time to support environmental sustainability, public health, economic activity, and cultural significance (NACTO, 2016).

Street tree

A street tree means any tree growing in or upon any city managed street. These trees are planted in the public right-of-way, usually in the planting strip (space between sidewalk and road) or in the absence of sidewalks. Trees have pedestrian safety and traffic calming effects by buffering pedestrians from vehicles along (Rahaim *et al.*, 2014). Street trees planted in roadway divider strips or tree wells physically separate vehicles from pedestrians and help drivers distinguish the boundary between the street and adjacent areas where people walk.

Street trees are vital urban and suburban element that can transform the character of streets and provide numerous environmental, aesthetic, cultural, and economic benefits (Trees, 2016).

Ecosystem service

Ecosystem services are the benefits that people get from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits.

Supply

It is the ability of an area to provide a specific set of these ecosystem products and services over a defined period.

Demand

Is an ecosystem good and service currently consumed or used in a particular area over a given period, not considering where ecosystem services are provided(Müller and Burkhard, 2012).

Well-being

Human well-being has multiple constituents, including basic material for a good life, freedom and choice, health, good social relations, and security. Well-being is at the opposite end of a continuum from poverty, which has been defined as a "pronounced deprivation in well-being." The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances(Reid, 2005).

Nature-based solution

Defined as measures to protect, sustainably manage, and restore natural or modified ecosystems that effectively and adaptively respond to societal challenges, simultaneously providing human well-being and biodiversity benefits.

Ecosystem service and street tree

Street trees, also known as public right-of-way trees, are an important component of public green infrastructure in many cities. The benefits of street trees include increased sustainability and a reduced in environmental concerns. These benefits are often referred to as ecosystem services and range from improved air quality to reduced storm water runoff to aesthetic value.

## **2.2** Theoretical Literature review

### **2.2.1** Functions of street trees

Urban trees offer a variety of advantages due to the variety of tasks they carry out. Sometimes a benefit comes from a tree's ability to do more than one function. For instance, trees can provide shade, evapotranspiration, and amenity benefits while also assisting with user comfort in hot weather. The following are some of the many advantages that trees can offer.

Shade and evapotranspiration: Are separate but related functions in which shading from tree canopies and water evaporation through canopies significantly reduce temperatures in urban areas (Gillner et al., 2015, Coutts et al., 2016), Shading from trees in car parks can also reduce emissions from cars, through reducing evaporation from fuel tanks of cars in hot weather . Shade from trees in parking lots can also reduce vehicle emissions by reducing evaporation from vehicle fuel tanks in hot weather (Scott ,1999).

Windbreaks: Trees can “act as windbreaks and alter airflows, thus affecting energy transport in the atmosphere, and this can reduce energy loss from buildings” (McDonald *et al.*, 2007). Leser (2013) identified that depending on the extent of tree canopy cover and density, wind speeds can be reduced by up to 10%. However, the effect varies depending on the tree species, planting orientation, and streetscape.

Carbon sequestration: Carbon sequestration helps mitigate the effects of climate change. The sequestration and storage of carbon by urban trees is important, even though they form a relatively small portion of the world's forests (Leser, 2013). Street trees continue to sequester carbon, but at a slower rate as they grow older, with internal decay of trunks and branches reducing carbon storage by up to 15% (Orozco et al., 2018). When street trees reach the end of their useful lives, they can either be left in place to offer habitat (dead trees can provide essential habitat) or utilized in methods that allow the carbon to stay stored in the wood, which increases the benefits of carbon sequestration.

Noise absorption/attenuation; Urban areas can be very noisy, especially when hard surfaces (such as glass building fronts) reflect traffic noise. Emerging research showed that in areas with increased tree canopy, human, and weather-produced sounds such as traffic and wind noise are reduced, while sounds associated with animals such as bird songs are greater (Laverne and Kellogg, 2019).

Interception of rainfall: In cities, heavy rains often cause rapid water runoff. This causes soil erosion, increases the risk of flash flooding, and spreads debris into rivers and other bodies of water, particularly where large areas of impermeable surfaces that don't absorb water (roads, cement pathways, rooftops) contribute to rapid water runoff (Baptista *et al.*, 2018). Water interception by trees can reduce both the volume and speed of water runoff in urban areas. Healthy urban trees intercept rainfall and temporarily store part of the water on leaves and branches, which slows the rate that the water reaches the ground, and consequently reduces the peak flow of surface flow (Baptista *et al.*, 2018). This in turn reduces the extent of soil erosion and the amount of dirt, litter and pollutants washed into stormwater drains during rainfall.

Amenity and nature connection**;** Urban areas with healthy trees are known to have more amenities and are more livable as they encourage a connection with nature.

Timber and food production**:** Urban trees are cut down and removed when they reach the end of their useful or safe lives, even though they produce food for a variety of animal species and occasionally humans. However, in a sustainable setting, these trees are replaced with new ones while the removed material is reused. Common uses for this material include mulching for landscape purposes, and drying/splitting for firewood, or timber. The use of urban trees for food and timber is common in some parts of the world (Kaoma and Shackleton, 2014),

Provision of habitat**:** Urban trees give a variety of habitat benefits. For a variety of birds, animals, reptiles, and insects, this can entail providing food sources (seeds, nectar, leaves, pollen, fruit, etc.), shelter from the heat and cold, resting and nesting chances, protection from predators, and safe transport corridors. For instance, establishing tree corridors throughout a city gives birds and insects a place to rest while migrating about the city and offers them foraging possibilities. Tree canopies provide shade during hot weather and can be used as shelter by a variety of species.

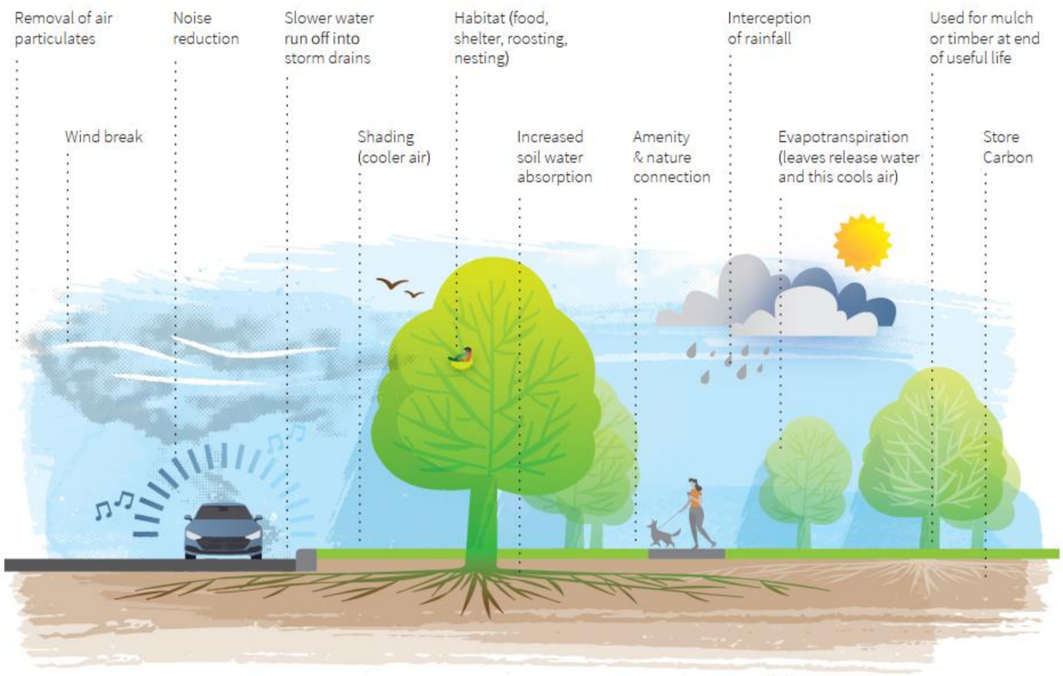



*Figure 2.1 Functions of healthy urban trees. Source :(Brack and Schirmer, 2020)*

### 2.2.2 The Benefits of street tree

Street trees are an important part of an urban forest. Urban street trees provide important benefits in terms of ecosystem services (Dobbs *et al*., 2017), including environmental, economic, and social benefits (Mullaney *et al*., 2015).

Environmental Benefits

- Carbon sequestration and storage. A single mature tree can absorb carbon dioxide at a rate of 21 kg/year and release enough oxygen into the atmosphere to meet the needs of two people.
- Shading of pavement, cars, and buildings, thereby reducing urban temperatures. Shading of asphalt surface can also extend the life of the asphalt.

- Removal of gaseous pollutants by absorbing them with normal air components through the stomata's in the leaf surface. (e.g., Sulfur Dioxide, Ozone, Nitrogen Oxide), plus capture and remove dust particles from the air.
- Acting as natural pollution filters. Their canopies, trunks, roots, and associated soil, filter polluting particulate matter out of stormwater flows and slow and reduce the flow of runoff, reducing the amount of pollution that is washed into drains and catchment areas. Trees also take up and utilize nutrients like nitrogen, phosphorus, and potassium that can otherwise pollute streams.
- Intercepting and reducing raindrop impact and runoff and thereby reducing erosion of exposed soils and siltation of creeks and drains.
- Provide habitat, roosting, and food sources for urban fauna.

Economic Benefits

- Improving economic performance by increasing the attractiveness of businesses and tourism destinations. It has been shown that people typically linger, shop, and dine longer on tree-lined streets.
- Reduce energy consumption and reduce the impact of the "urban heat island" through shading.
- Shops, apartments, and housing in well-planted areas usually attract higher rents and sale prices. Social and Psychological Benefits
- Calming traffic, slowing speeds, and providing a buffer between pedestrians and cars. They are also useful in delineating and signifying curves in a street.

- Improved sociological benefits with studies showing a strong correlation of well-planted areas with reduced social services, domestic violence, and strengthened community ties.
- Creation of feelings of relaxation and well-being. Hospital patients, for example, are shown to recover quicker and with fewer complications when in rooms with views of trees. Workers and students are also shown to be more productive when their environments have views of trees.
- Improving comfort and general amenity as street tree canopies can shade pedestrians, diminish traffic noise, screen unwanted views, and reduce glare.
- Defining precincts and links with history. Tree-lined streets can provide orientation and contribute to the overall urban character.
- Providing a human scale that contrasts with apartments and larger buildings that can otherwise dominate some streets.
- Providing seasonal interest and natural beauty through foliage and its interesting leaf patterns, flowers, bark, fruit, and canopy.

### 2.2.3 Tree structure

**Tree Size**

With site constraints such as verge widths, overhead power lines, building setbacks, and vehicle clearances considered, the final mature size is in scale with the relevant street. The ideal size range should neither be too huge to dominate and create serious issues nor should it be too little to not contribute to the street's amenities (damage & nuisance). In other cases, the limitations imposed by the street environment will limit the final size of the street. Depending on the specific design and physical conditions, the following tree sizes are planted: small trees: height 6-8 m, crown spread 5 m, medium trees: height 10-12 m, crown spread 8 m, large trees: height 16 ~ 20 m, trees with a canopy spread of 16 m (Sutherland, 2008). As shown in Figure 2.1, the bigger the tree, the bigger the canopies give us greater benefits.

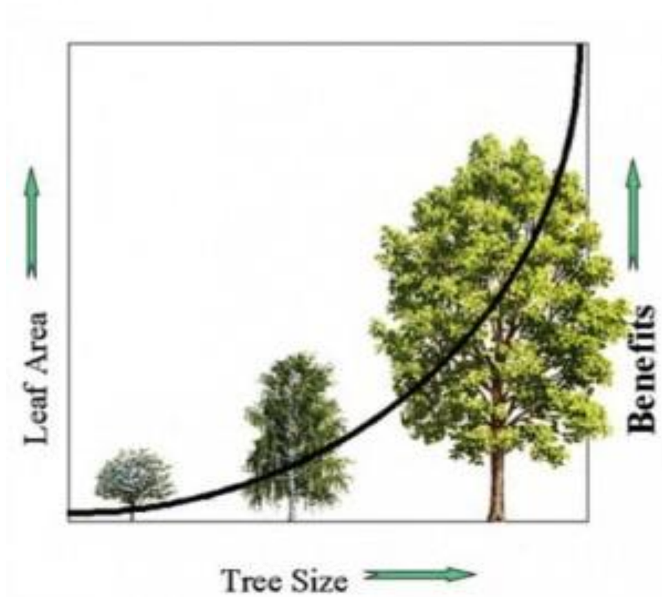



*Figure2.2. The relation between tree size and its benefits.* *source:(www.urbantreealliance.org/resources/why-trees/)*

**Tree Form**

To be a successful street tree, a species must be chosen for its predictable growth pattern and form. A street tree should have a single, straight trunk (to reduce conflicts with pedestrian and vehicle traffic) and a stable branch structure (to reduce risks caused by inherent flaws), with a clear trunk height (free of lateral branches) of at least 3 meters from the ground.

**Tree canopy**

The tree's canopy should have broad, umbrageous, or domed branches and foliage. Regularly placed, large, domed trees with interlocking canopies are a part of the classic vision of a street, giving the route a leafy ceiling.

**Tree species characteristics**

- Canopy size and crown density; a wider canopy and high density of leaves and branches in the crown of the tree will provide more shade.
- Leaf type and color; the ability to reflect solar radiation is normally increased in trees with lighter leaves or leaves with certain characteristics, including hairs or waxy surfaces.
- Evapotranspiration rate: the higher the rate, the more cooling a tree will provide.
- Drought tolerance; higher tolerance to drought ensures that evapotranspiration will occur for longer.

**Green space characteristics**

- Size of the green space; the larger the green space, the greater is its cooling capacity.
- Design of the greenspace; including the shape of the green space; choice of trees, shrubs and groundcover; plant arrangement and topography.
- Distance between green spaces; cooling from a greenspace can extend beyond its borders but only up to a certain distance. Green spaces need to be optimally placed if they are to provide effective cooling to a whole neighborhood.

**Site conditions**

- Water supply: an adequate water supply is crucial to ensure evapotranspiration and the long-term health and growth of trees and shrubs. Design strategies such as using sustainable drainage systems can help achieve this.
- Ground cover: the use of vegetated groundcover and permeable pavements will allow rainwater to infiltrate the soil.
- Soil quality: techniques such as soil profiling, mulching, and the incorporation of organic matter (such as green waste composts) will improve the quality and water-holding capacity of soils, which will help improve water retention and accelerate plant establishment and growth.
- Tree planting pits: the pits that are dug when the tree is planted should match species requirements and be proportional to the canopy projection.
- Landscaping: the aim should be to offer a microclimate favorable to plants, which seeks to minimize barriers to growth such as restricted access to light and poor airflow

**Sustainable Tree Selection**

Selecting the right species for urban environments is crucial for sustainability. Key considerations include:

- Native vs. Non-native Species: Native species are often preferred for their adaptability and support of local ecosystems. However, non-native species may be selected for specific urban challenges.

- Diversity: A diverse tree population reduces the risk of widespread disease and pest outbreaks.
- Climate Adaptability: Trees must be resilient to local climate conditions, including temperature extremes and precipitation patterns.
- Soil and Space Requirements: Understanding the soil conditions and available space helps in selecting species that will thrive without causing infrastructure damage.

**Sustainable Management Practices**

Effective management practices ensure the long-term health and sustainability of street trees. Key practices include:

- Proper Planting Techniques: Ensuring correct planting depth, soil preparation, and initial care.
- Water Management: Implementing efficient irrigation systems and drought-resistant species to conserve water.
- Pruning and Maintenance: Regular pruning to remove dead or diseased branches, promote healthy growth, and prevent hazards.
- Pest and Disease Management: Integrated pest management (IPM) strategies to minimize chemical use and promote tree health.
- Community Involvement: Engaging local communities in tree planting and care to foster a sense of ownership and stewardship.

### 2.2.4 Green infrastructure (GI) and street trees

Green Infrastructure (GI) refers to a network of natural and semi-natural areas, features, and green spaces that deliver a wide range of ecosystem services. These services include air and water purification, climate regulation, and recreational opportunities. GI encompasses a variety of elements such as parks, street tree, green roofs, wetlands, and urban forests (Wolf, 2005). Street trees, as a component of GI, play a significant role in enhancing urban environments by providing numerous ecological, social, and economic benefits (McPherson *et al*., 2007). The primary goal of GI is to create interconnected networks that support biodiversity, improve water management, and enhance the quality of life for street user.

### 2.2.5. Ecosystem service of a tree

Street trees play a crucial role in providing a range of ecosystem services, which encompass the benefits that individuals derive from ecosystems service to provide valuable contributions to human well-being and the environment.

Trees achieve these benefits through ameliorating climate and environmental extremes (e.g. heat island effects, noise pollution, air pollution); providing environmental benefits (e.g. carbon storage and sequestration, habitat, and ecosystem restoration), and being pleasant to live near (providing benefits for mental health and wellbeing) (Brack and Schirmer, 2020).

The ES provided by street trees, such as storing carbon, regulating the air quality (large healthy trees absorb 60-70 times more air pollution than smaller trees) (McPherson *et al*., 1997), reduce daytime temperatures between 5 and 20°C (Mullaney *et al*., 2015), as well as improved street amenity, encourages pedestrian activity, especially in areas of socio-economic disadvantage (Van Dillen *et al*., 2012). Street trees also appear to be a feasible option for ameliorating the urban heat-island effect (Whittlesea City Council, 2019).

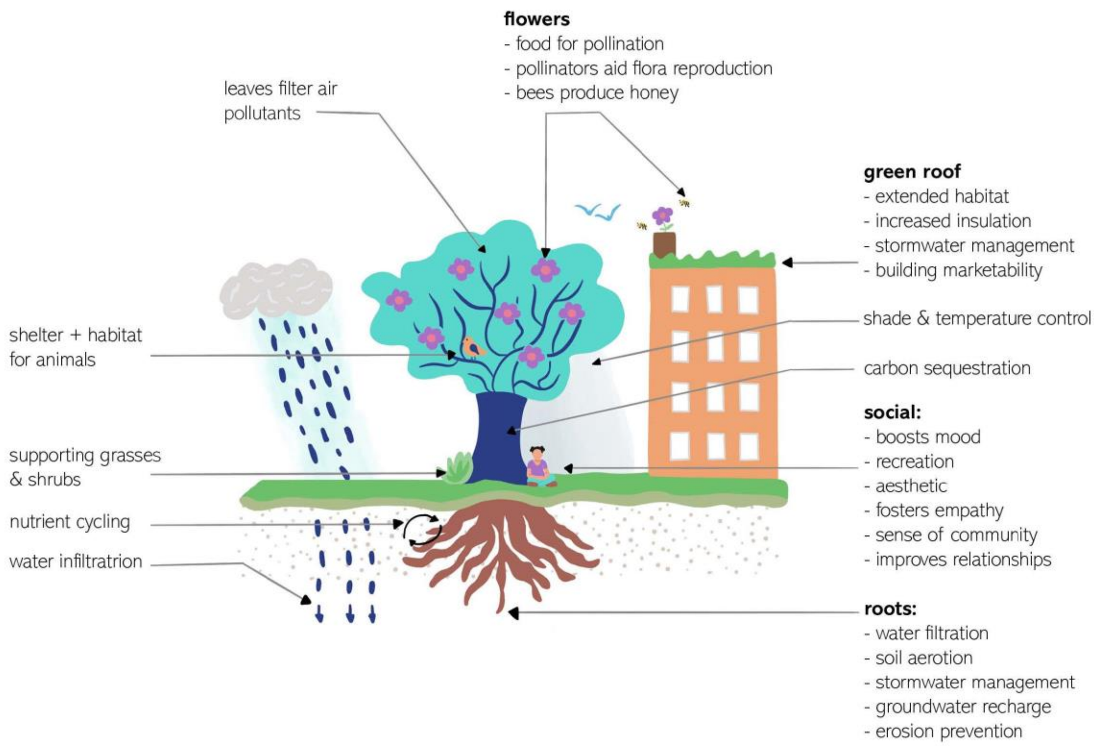



*Figure 2.3. Important services given by a tree. Source: https://clearinghouseproject.eu/ecosystem-services-of-a-tree/*

Temperature regulation

One ecosystem service that trees provide is temperature regulation. Tree planting is a highly effective strategy for cooling urban environments (Lanza and Stone, 2016). In summer, leaves and branches typically reduce sunlight and solar radiation below the tree canopy by 70–90%, depending on the tree species (Suter, 2008). By providing shade, street trees help to reduce the phenomenon referred to as the urban heat island effect, in which urbanized areas experience higher temperatures – 1 to 7°F higher in the day than outlying areas due to the prevalence of buildings, roads, and other infrastructure that absorb and re-emit the sun's heat more than natural landscapes (US-EPA, 2016). Shaded surfaces may be 20 to 45°F cooler than peak temperatures in non-shaded areas (McPherson *et al*., 2007).

Evapotranspiration associated with trees can in the future reduce temperatures in urban areas. Evapotranspiration is the combination of evaporation from land and transpiration, or the opening of stomata and release of water vapor, from plants. This has a cooling effect on the atmosphere. Evapotranspiration increases as temperature increases and can lower peak summer temperatures by 2-9°F (US-EPA, 2016). Street trees provide benefits in winter as well by acting as a windbreak.

Filter air pollutants

Air pollution removal: amazing rates of air pollution filtration are achieved by trees. They eliminate a variety of typical air pollutants, including particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide.

Sequester Carbon

Urban trees offer benefits in terms of atmospheric carbon reduction (Nowak and Sigmund1993; Jim and Chen 2008), transform CO2 into above and belowground biomass, and store carbon in the form of stems, branches, and roots (McPherson *et al*.,1997; Jo 2002; Nowak and Crane 2002), additionally; trees reduce the effects of climate change. They remove carbon dioxide from the environment and store it in their trunks as carbon. The most prevalent greenhouse gas causing climate change is reduced by trees.

Stabilize soils

Trees improve soil quality. Maintaining your soil's health supports vegetation, the structural integrity of the surrounding land, and nutrient recycling. Furthermore, healthy soils will promote healthier trees and reinforce the benefits previously mentioned from the tree's ecosystem services.

Provide shelter for living organisms.

Street trees provide an important ecological role in the urban environment. They create habitats for birds, insects, and wildlife and support the conservation of urban biodiversity. Native, denser, and larger trees typically provide better habitats for species such as birds(Wood and Esaian, 2020).

Improve occupant's mental, physical, and well-being.

These regulating services have numerous social benefits, ranging from public health to enhancing the pedestrian realm. A reduction of pollution has been shown to reduce negative health consequences associated with poor air quality. The cooling effect of trees can reduce heat-related illness, which is particularly important in an urban area.

The presence of trees makes people more likely to walk and participate in outdoor activities. Trees also filter airborne pollutants, reducing causes of asthma and other respiratory problems (Ulrich, 1984).

Storm water management

Trees also aid in storm water management. By intercepting rainwater and reducing and filtering runoff in the canopy and root zone, street trees contribute to storm water management and improve the water quality in receiving water bodies and groundwater (Salmond et al., 2016). By drawing moisture from the soil, trees increase the soil water storage capacity during rainfall events. They also enhance permeability roots loosen soils as they grow, which increases infiltration.

Trees with tap roots and deeper and more vertical roots have been found to promote greater infiltration than species with fibrous roots and more lateral, shallower roots (Zhang *et al.*, 2019). Greater infiltration reduces storm water runoff, helps to mitigate flooding, and promotes groundwater recharge. Increasing the prevalence of street trees enhances storm water management in the city. Trees filter air pollutants and capture and store carbon dioxide, which helps to improve local air quality and mitigate greenhouse gas (GHG) emissions (US-EPA, 2016).

### 2.2.6 Major ecosystem service selected.

The ecosystem services examined in this study are local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place.

Local climate management:

The cooling effect provided by trees is directly related to tree size, canopy cover, tree location, and planting density. As much as 80% of the cooling effect of trees results directly from shading (Shashua et al., 2015). Street trees can reduce daytime temperatures by between 5°C and 20°C, making everyday activities more pleasurable and healthier (Burden, 2006). Street trees also enhance community economic stability by attracting businesses and tourists as people tend to linger and shop longer along tree-lined streets.

Air quality regulation**:**

Street trees play a significant role in mitigating air pollution and improving air quality in urban areas. Street trees can effectively remove air pollutants such as particulate matter and nitrogen dioxide, thus contributing to improved air quality and human health (Nowak and Crane, 2002). In addition; street trees could intercept and absorb airborne pollutants, reduce air temperature, and enhance air quality in urban environments (Escobedo et al., 2019).

Storm water management:

Increases in impervious surface area and soil compaction, due to urbanization, reduce water infiltration into soil and increase storm water runoff and peak flow rates. For example, urban runoff from summer rainfall is much higher from asphalt (62%) than from surfaces with tree pits (20%) or turf (<1%), highlighting the effect that trees can have on storm water reduction (Escobedo et al.,2013). Leaves and branches intercept, absorb and temporarily store water before it evaporates from tree surfaces or gradually infiltrates into the soil. Trees absorb 30 percent of the precipitation through their leaves and another 30 percent through their roots (Macdonald et al., 2007). Depending on the site conditions and the type of tree, street trees can capture significant amounts of rainwater. Street trees' ability to capture less storm water runoff has the potential to drastically lower both the amount of expensive storm water drainage infrastructure and the peak catchment runoff volumes.

Aesthetics value:

Trees add beauty to their surroundings by adding color to an area, softening harsh lines of buildings, screening unsightly views, and contributing to the character of their environment. Trees have also proven to contribute to a community’s economy and way of life. Depending on species, maturity, quantity and location, property values increase 5 to 15 percent when compared to properties without trees.

Trees enhance their surroundings in many ways. Trees planted along and around buildings provide a distraction for the eye, softening the background and screening unsightly views. Trees also contribute eye-catching colors to their surroundings, from the different shades of green found in the leaves, the colors found in flowering trees and sometimes even the bark of the tree.

Recreation and human health**:**

Recreation is important ecosystem services provided by urban street trees and have positive impact on recreational activities and human well-being. The presence of street trees significantly increased the use of public spaces for recreational activities such as walking, socializing, and leisure (Kuo and Sullivan, 2001).  Street trees not only provide aesthetic value but also encourage outdoor activities and create a sense of place; thereby enhancing recreational opportunities for the local community (Ward Thompson et al., 2016). In addition street trees can serve as gathering spaces, fostering social interaction and community engagement. McFarland and Kaczynski, 2009 highlighted that the presence of street trees provides opportunities for people to come together, socialize, and engage in recreational activities.

Biodiversity:

Street trees also provide habitat for urban fauna, and some fauna species are so well-adapted to urban environments that they are more abundant in cities than in surrounding natural vegetation (Alvey, 2006). However, fauna abundance is often lower in the inner city, where tree density is lower, than in suburban and outer-urban areas (Davis and Humphrey, 2012). The type and height of street tree can also influence fauna abundance and fauna diversity, and planting a diversity of native tree species is often recommended for preventing homogenization of the urban fauna (Alvey, 2006). Many diverse species make use of the flowers, fruits, leaves, buds, and woody sections of trees. Decomposition from bacteria and fungus found in tree components facilitates nesting for some birds and improves soil fertility and structure for furrowing by other land animals.

Food provision:

The food provision ecosystem service provided by street trees is a potential contribution to urban food systems. While street trees may not be the primary source of food production, they can still play a role in enhancing local food availability and accessibility. Different types of tree species, such as fruit-bearing trees, can produce edible fruits that contribute to local food supplies. Additionally, the importance of incorporating agroforestry practices, including street trees, into urban planning to support food security and community resilience (Orsini et al., 2014)

Sense of place:

The sense of place ecosystem service provided by street trees emphasizes the role of trees in creating a distinct and meaningful identity for urban areas. Street trees contribute to a sense of place by enhancing the aesthetic appeal and character of neighborhoods, fostering a connection between people and their environment, and promoting social cohesion. Street trees were highly valued by residents and contributed to a stronger sense of place, as they provided a visual landmark, created a pleasant and inviting atmosphere, and symbolized the identity of the neighborhood (Beery and Jönsson, 2017). Additionally, a study by (Kothencz et al., 2017) investigated the impact of street trees on social cohesion and sense of place in urban communities. The research revealed that neighborhoods with a higher density of street trees had stronger social ties among residents and a greater sense of belongingness and attachment to their surroundings.

*Table 2.1 Selected ecosystem service*

| Ecosystem service | Ecosystem Service Category | Benefits / Values provided |
|---|---|---|
| Regulating services | Local climate regulation | Thermal comfort |
| | | Shade provision |
| | Air quality regulation | Dust removal |
| | | Smoke-free air |
| | | Noise reduction |

| | | |
|---|---|---|
| | Storm water management | Flood/runoff control |
| | | Trapping Rainwater |
| Cultural service | Aesthetic value | Inspiration |
| | | Availability of seasonal beauty foliage tree |
| | | Longer pavement life |
| | Recreation and human health | Physical exercise |
| | | Emotional and psychological health |
| | | Social setting |
| | | Space for recreation |
| | Biodiversity | Tree species diversity |
| | | Availability of birds and other wildlife |

### 2.2.7 Streetscape Elements and Street Tree

Streets become welcoming, engaging, and usable place for people when it is filled with trees and landscaping, lighting, pedestrian furniture, paving, and other aspects. Streetscape elements are those functional and aesthetic items in pedestrian spaces that provide amenity and utility to pedestrians and other street users.

- Urban Forest; All plantings in the right-of-way, including street trees, understory planting (ground landscaping), and above-ground planting (planter boxes and hanging baskets)
- Storm water Management Tools: Plantings, permeable paving, and other facilities to detain and infiltrate storm water.
- Lighting; Both roadway and pedestrian lighting, including poles and fixtures, and light quality
- Paving; Standard materials as well as special paving treatments

- Site Furnishings; Other pedestrian amenities and functional elements, including benches and seating, bicycle racks, bollards, flower stands, kiosks and gateway monuments, news racks, parking meters, public art, sidewalk restrooms, traffic and parking signs, trash receptacles, and way finding signage.
- Utilities and Driveways; Overhead, surface-mounted, and sub-surface utilities including all poles, trenches, boxes, vaults, vents, and valves, and driveways to access properties.

### 2.2.8 Ecosystem Disservice from Urban Street Trees

Urban street trees are an essential part of urban ecosystems, providing various ecosystem services such as improving air and water quality, reducing urban heat island effects, and enhancing overall human well-being. However, recent research has also highlighted the potential for urban street trees to contribute to ecosystem disservices, such as increasing, Disruption of Underground Utilities, air pollution and exacerbating urban heat island effects.

Impact on Urban Water Cycles

Livesley et al. (2016) emphasize the role of urban street trees in impacting urban water cycles. They found that while urban street trees provide benefits such as reducing stormwater runoff and improving water quality, they can also lead to ecosystem disservices by increasing the demand for irrigation and contributing to soil compaction, which can negatively affect water infiltration and groundwater recharge.

Impact on Urban Heat Cycles

In their study, Livesley et al. (2016) also investigated the impact of urban street trees on urban heat cycles. They found that while trees can provide cooling effects through shading and evapotranspiration, they can also contribute to the urban heat island effect by trapping heat and reducing air movement, especially in areas with high tree canopy cover.

Salmond et al. (2016) further examined the relationship between street trees and urban heat. They found that the cooling effects of street trees are highly dependent on tree species, size, and distribution, and that improper tree selection and placement may lead to increased energy consumption for cooling, thus acting as an ecosystem disservice.

### Impact on Urban Pollution Cycles

Another ecosystem disservice associated with urban street trees is their potential to impact urban pollution cycles. Livesley et al. (2016) found that while trees can mitigate air pollution by removing pollutants through leaf surfaces, they can also release volatile organic compounds and pollen, contributing to air quality degradation.

### Impact on Disruption of Underground Utilities

Street trees have the potential to disrupt underground utilities such as water pipes and sewer lines as their roots grow and expand. Root intrusion can damage infrastructure, leading to costly repairs and service disruptions. In some instances, tree roots may even cause structural damage to buildings and roads, posing safety hazards to residents (Dobbs *et al.*, 2017).

### 2.2.9 Challenges of street tree Development and Management

(Shikur, 2012) described the challenges facing street trees in Addis Abeba, including poor soil structure, conflict with infrastructure, water availability, compacted soil conditions, and space allocation. Although the issues mentioned above also apply to the situation in Hawassa, the experts who participated in the focus group discussions indicated that the main issue with street tree challenges and development is conflict with infrastructure, conflict with vehicles, and conflict with people. Lack of aesthetic values, problems with the mature size, some trees failing, wrong species selection, lack of experts to deal with street trees and institutional barriers. Street trees are easily subject to stresses due to their proximity to atmospheric pollutants, poor drainage, inhospitable soil, mechanical damage, high and low ambient temperatures, and lack of space for growth (Ware, 1994; Sæbø et al., 2005; Thaiutsa et al., 2008). Effective management of urban street trees is essential to maximize their benefits. This includes selecting appropriate tree species for the urban environment, ensuring proper planting and maintenance, and addressing potential threats such as pests and diseases. Community engagement and education are also critical, as they can help raise awareness about the importance of street trees and encourage residents to participate in tree planting and care.

### 2.2.10 Street trees as Nature based solution (NBS).

Street trees have been recognized as nature-based solutions, which are approaches that utilize natural elements to address environmental challenges and enhance the resilience and sustainability of urban areas. the benefits of street trees as nature-based solutions such as cooling effects and urban heat island mitigation, stormwater management and water quality improvement, carbon sequestration, climate change mitigation, biodiversity conservation and habitat creation.  Examples of NBS include the preservation of natural woodland, the creation of a constructed wetland, the construction of a vegetated roof, or the planting and maintenance of street trees (Eggermont et al., 2015).

Street trees play a crucial role in mitigating the urban heat island effect by providing shade and evaporative cooling. (Coutts et al., 2016) demonstrated that street trees can significantly reduce surface and air temperatures in urban areas, helping to create more comfortable and cooler microclimates also Street trees contribute to stormwater management by intercepting and absorbing rainwater, reducing stormwater runoff, and enhancing water infiltration (Escobedo et al., 2011) ,the ability of street trees to capture and store rainfall, thus reducing the burden on stormwater infrastructure and improving water quality by filtering pollutants.

In addition, Street trees contribute to carbon sequestration and help mitigate climate change by absorbing and storing carbon dioxide (Nowak et al., 2013). Street trees provide habitat and refuge for various plants and animal species, contributing to urban biodiversity conservation. (Pauleit et al., 2019) emphasized the importance of street trees in supporting urban wildlife and enhancing ecological connectivity within urban landscapes.

There are five principles of nature-based solutions (Kabisch et al., 2022).

1. Systemic understanding

2. Benefiting people &biodiversity: aims at a balanced delivery of multiple benefits for humans and non-humans that need to be based on understanding of the local context
3. Inclusive solutions for the long term: to make NBS sustainable and last over time.
4. Context consideration
5. Communication &learning: points to NBS depending on the understanding and support of citizens

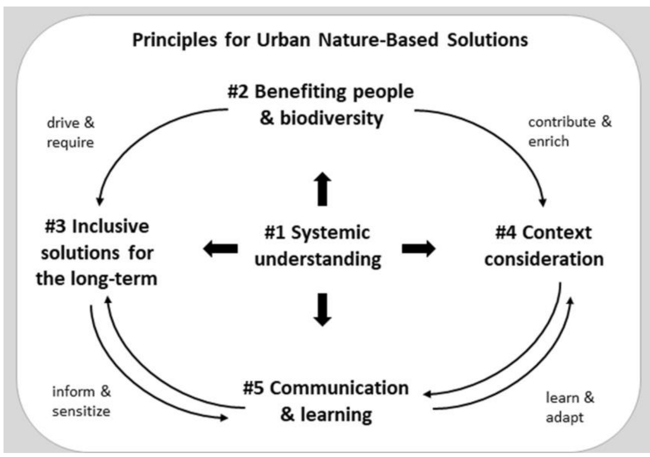
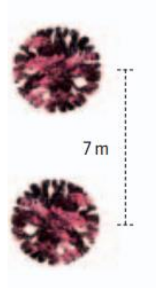
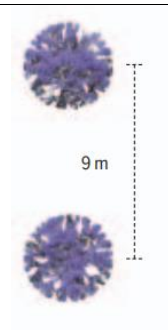
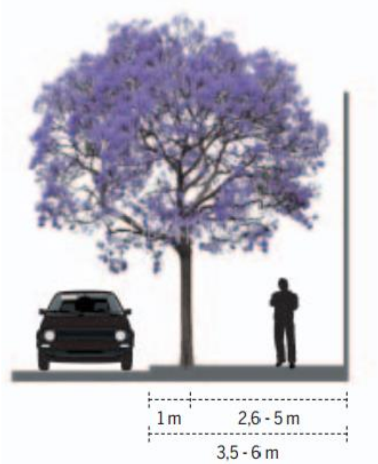



*Figure 2.4 Principle for urban nature-based solution : source :(Kabisch et al.,2022)*

### 2.2.11 Guidelines for planting a tree.

The minimum space between trees is specified in the planting rules to ensure that they have enough to grow without obstructing city roadway services. Maintenance is decreased by effective planting. In accordance with the pavement width, the streets are separated into three categories, and in each category, a different set of planting standards is followed.

*Table2.2Guidelines for planting a tree*

| | | |
|---|---|---|
| **Narrow streets:** those with a pavement width of less than 3.5 meters, where small species are planted. Planting on pavements less than 2.5 m wide should be avoided. When buildings have balconies or overhangs and the crown of the adult tree would be expected to come within 0.5 m, planting should be avoided. The minimum distance between trees and lamp posts should be 3 m, and 7 m the planting distance between trees. | <br> | <br> |
| **Medium-width streets:** those with a pavement width of between 3.5 and 6 m, where medium-sized trees can be planted.<br>The minimum distance between trees and lamp posts should be 4.5 m, and 9 m<br>the planting distance between trees. | <br> | <br> |
| **Wide streets:** those with a pavement width of more than 6 meters, where large<br>trees can be planted. The minimum distance between trees and lamp posts should be 6.5 m, and 13 m the planting distance between trees. In all cases, the distance between trees<br>and traffic lights and other signs must be<br>greater than 3 m, and greater than 1 m between trees and dropped curbs. | <br> |  |

*Source: (Habitat Urbà.,2011)*

### 2.2.12 Standard plant spacing in Ethiopia.

Street tree spacing shall be determined by the expected mature size of the tree: (MUDHo, 2015).Generally, trees should be planted with the following spacing:

• small trees (< 7 m crown diameter at maturity) should be planted 6 m on center;

• medium trees (5-11 m crown diameter at maturity) should be planted 8 m on center;

• large trees (> 11 m crown diameter at maturity) should be planted 10 m on center.

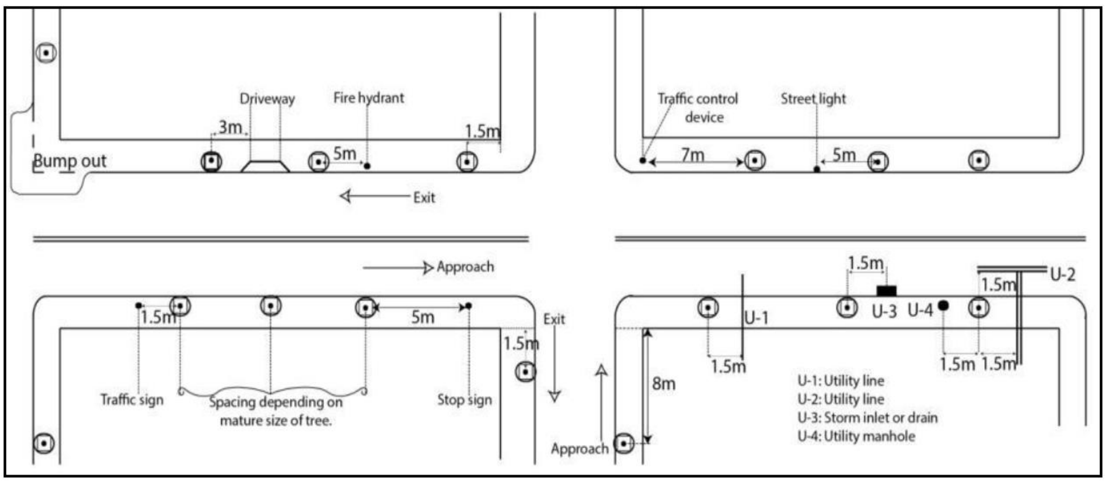



*Figure 2.5. Overview on clearance standards for tree location. Source: (MUDHo, 2015)*

- On medians, the minimum distance between tree stem and an intersection shall be 8 m. The height of plantings near intersections should be restricted so that sight lines are not obstructed.
- On medians, the minimum distance between tree stem and a pedestrian crossing shall be 3 m to allow sight clearance for pedestrians onto the street.

When planting street trees, the following points are taken into account to ensure the necessary services: infrastructure considerations, traffic and pedestrians, sight lines at intersections, clear zone planning considerations, livable areas, street trees and public facilities and buildings, placement of street trees and building sidewalks, species selection, and safety considerations (MUDHo, 2015).

## 2.3 Conceptual Literature review

The conceptual framework of this study is based on the ecosystem services cascade (ESC) model, which illustrates the relationship between the ecological structure-process and the benefits to human welfare derived from street tree ecosystem provision. The ESC was initially proposed by (Haines-Young and Potschin, 2010), and it serves as a chain structure that connects landscape structural processes and the resulting benefits (Andersson-Sköld *et al*., 2018).

The method employed in this study aims to be applicable ecosystem service assessments, and understanding the current or potential services and values of urban street ecosystems is required. It allows for the estimation of supply-side and demand-side aspects of ecosystem services, as well as identifying the gap between them (Malinauskaite, L *et al*., 2021).

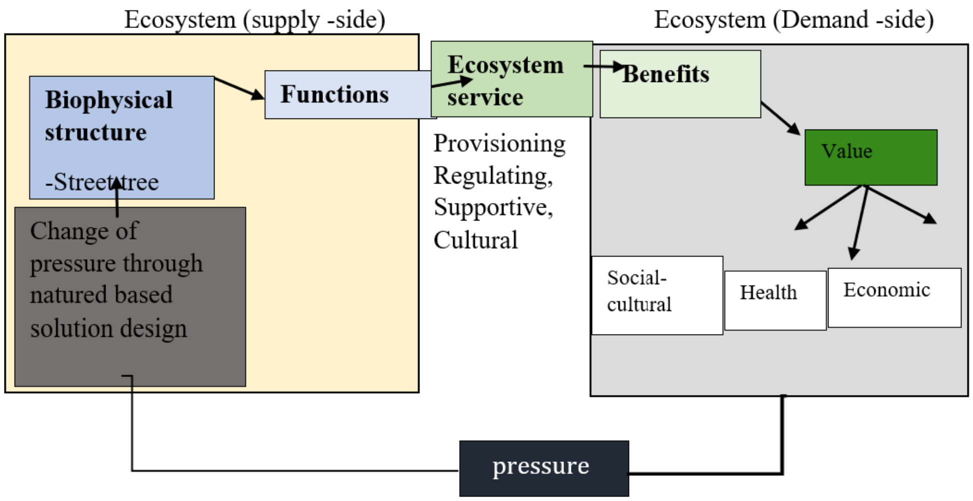



*Figure 2.6. The cascade model framework for assessing the supply and demand of the ecosystem of a street tree modified from Potschin and Haines-Young (2018)*

The method consists of several steps designed to link the supply and demand of ecosystem services by measuring their functions and benefits.

The five main stages involved in the emergence of ecosystem services connect biophysical structures and processes to the benefits and values provided by a given system(Potschin and Haines-Young, 2018, Haines-Young and Potschin, 2010; Martín-López *et al*., 2014). In the context of this study, the functions and processes of street trees are considered on the supply side of the flow diagram. These ecological benefits contribute to the formation of ecosystem services and subsequently provide diverse benefits to human well-being on the demand side.

The model demonstrates an overlap between the ecosystem services on the supply and demand sides, specifically within the context of existing street trees. The gap between the supply and demand of ecosystem services is located at the intersection of these two aspects. By adopting this conceptual framework and methodology, the study effectively analyzes the provision and demand of ecosystem services provided by street trees in urban areas. It provides valuable insights into the current state of these services and the future demand of this service.

# Chapter Three: Research Methodology

## 3.1 Description of the Study Area

Hawassa is a city located on the shores of Lake Hawassa on the fringes of the Great Rift Valley. It is located 273 km from Addis Ababa, and is geographically located between $6^0$55'0" to $7^0$6'0" latitude North and $38^0$ 25'0" to $38^0$ 34'0" longitudes east. The mean annual total rainfall and mean monthly temperature range from 1000 to 1400 mm and 12.6°C to 30.1°C, respectively (SNNPRS, 2005). The boundaries of Hawassa City are Lake Hawassa to the west, Oromia region to the north, Wendogenet woreda to the east, and Shebedino woreda to the south. The area managed by the city administration is 157.2 square kilometers, divided into 32 kebeles and 8 sub-cities. These eight sub-cities are Hayek Dare, Menehariya, Tabor, Misrak, Bahile Adarash, Addis Ketema, Hawela-Tula, and Mehal Ketema sub-cities. The city currently serves as the Sidama Region`s administrative center and Hawassa City. According to projections of the central statistics authority of Ethiopia, the city's population is estimated to be 436,992 in 2012 EC. The population gender breakdown will be relatively evenly split between males (224,907 /51.4 %) and females (212,085 /48.6%). Of the total population of the municipality, 292,525 people live in urban areas and the remaining 144,467 people live in rural areas of the municipality.

The study was conducted on five different road sections in Hawassa City. These are From Tesfaye Gizaw to Atote Meberat, from Tabor Primary School to Hawassa Agricultural College, from Hawassa University Main Campus to Hawassa Textiles, from South Star

Hotel to Wanza Hotel, and from St. Gabriel's Church to Lake Fikir. Selected sites are based on road hierarchy, land use, and user traffic flow.

- **street hierarchy** classifies the roads based on their functions and qualities. It assists in the selection of the research location based on several street types that enable the user to experience various ecosystem provisions. **Main street hierarchy** that includes **PAS** principal arterial street**, SAS** sub arterial street and **LS** local street.

- **Land use:** There are many different types of land uses in the city, which includes commercial, administration, residential, recreational, and service districts. It is important to consider land use as one of the factors when choosing an appropriate site. Land use determines or influences the type of user activity and how they will use the space.

- **User traffic flow:** User traffic flow supports study site selection through the flow of road users with high, medium, and low user experience and is the major and final factor in site selection.

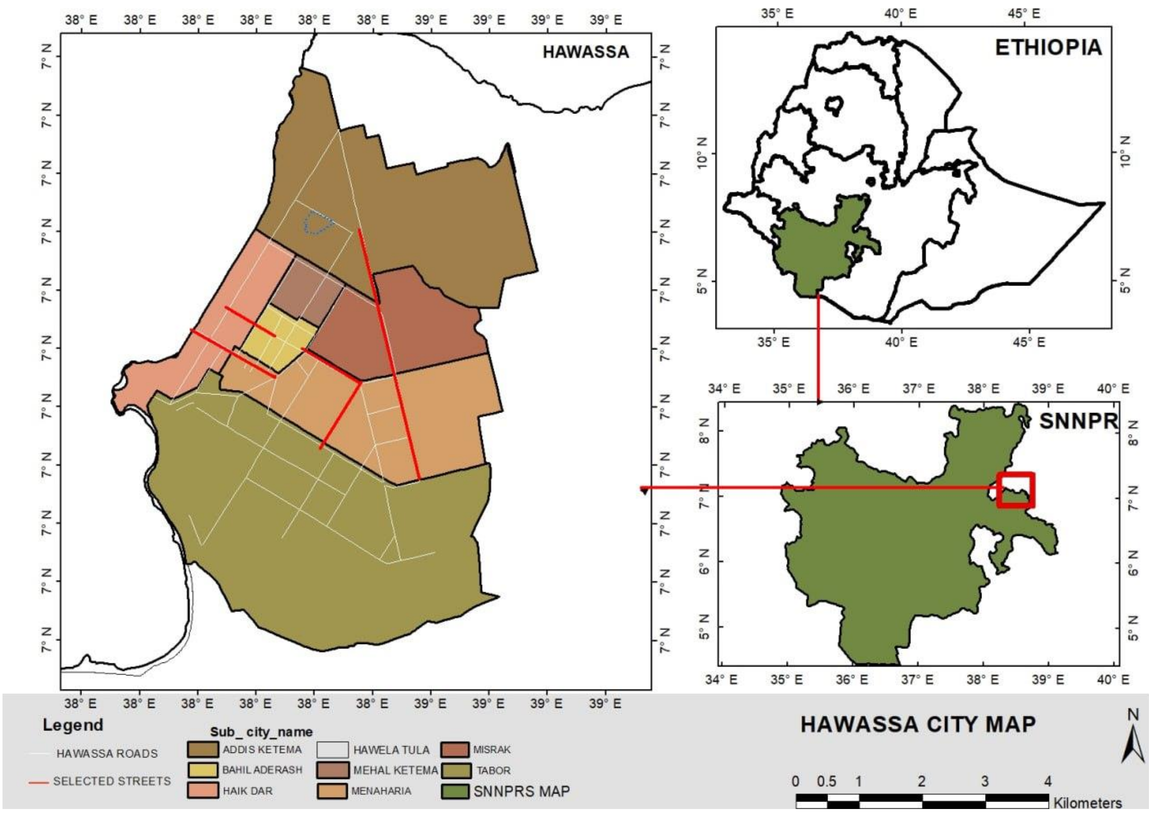



*Figure 3.1. Location Map of Hawassa*

## 3.2. Research Design

The research was exploring the current and future demands of ecosystem services that could be gained by urban street trees. Hawassa is a regional center with 436,992 inhabitants and is situated on the lakeside in the tropical savanna climate zone. The study used Q-methodology to rank a wide range of ecosystem services to measure opinions and perceptions (based on the method used by (Buchel and Frantzeskaki, 2015) assessing the future demand for ecosystem services in Hawassa. By Using the cascade model (Andersson-Sköld *et al.*, 2018) as a framework the researcher identify the functional traits from urban street trees that are needed to deliver desired future ecosystem services and propose specific ecosystem service that are not provided or highly demanded for use by future street tree plantation.

## 3.3. Research Approach

A mixed qualitative (key informant interviews and physical observation) and quantitative research (questionnaire survey) design was employed. A qualitative approach was used to assess the attitudes of informants towards the existing ecosystem service provision by street trees and for future ecosystem service provision from the street tree. This was achieved through in-depth key informant interviews and observation to obtain that complete information. Quantitative approach was used to generate numeric values and figures from the sample respondents' questionnaires.

## 3.4 Source of data

Primary data

Primary data is data collected directly from the first source. Primary data on the challenge of street trees, street scape element and the ecosystem services supply and demand by urban street trees was collected by using observation, questionnaires, and key informant interviews.

Secondary data

Secondary information was gathered from a variety of sources, including books, journals, and papers, reports from the municipal Sanitation Beautification and Green area Development and Management office.

## 3.5. Method of Data collection

The data was collected using direct observation, key informant interview and questionnaires.

### 3.5.1. Observation

The observation data was conducted by the researcher to characterize and understand the existing condition of the study area and cross-check to add the data obtained through other methods of data collection. This method was applied to observe the existing urban street tree species type, street scape element and current ecosystem service provision in the study area.

Direct observation is often useful to collect additional information about the topic being studied (Yin, 2009). Different methods are used to grasp the detailed information including observation checklists, texts, photographs, and videos were utilized to note what was present and what was absent. The assessment was conducted for each selected street, with 200 to 500 meters, to determine its condition based on the checklist.

### 3.5.2. Key informant Interview

The interview was well prepared to get important information from officials. Ten professionals from different sectors were selected for interview using purposive sampling method; 5 from Hawassa city development and construction Bureau (city beautification and urban greenery development), 2 from Municipality service standard expert, 1 from Hawassa infrastructure and construction office Bureau and 2 from Governmental project design and construction directorate (**Error! Reference source not found.**). Key informants were s elected based on their knowledge and involvement in urban planning managing and developing the street. The main instrument used to interview the officials was structured and semi-structured interviews, which contained open-ended questions whereby the respondents were given the chance to discuss all issues of their concern.

### 3.5.3. Questionnaires

The questionnaires are an essential tool for gathering primary data. Structured and pre-tested questionnaires were distributed by using kobo collector tool to individual street user (pedestrian, cyclist, vendors, car driver, and storefronts) at the study area. The questionnaires include closed and open-ended to get information about the research objectives.

## 3.6. population and size

The data was collected using simple random sampling technique from various street users, who passed through the street during the survey period. This approach helps to capture diverse perspectives and experiences of different street users. To determine the sample size of the participant respondents in the questionnaires, the researchers referred to the work of (Israel, 1992; Cochran and Banner,1977). They utilized a simplified formula (shown below) for determining the sample size when the population size is unknown or infinite. A total of 378 questionnaires distributed approximately every 200 meters along the street, considering both side (Li, Wang and Huang, 2011).

$$n = \frac{z^2}{4e^2}$$

Where,

$n$ = sample size

$e$ = acceptable sampling error ($e$ = 0.05)

$z$ = $z$ value at reliability level or significance level (z =1.96)

Based on the formula, the estimated sample size is 384.

**Determining the size of the tree's population**

The data collected specifically related to street trees, focusing on identifying the species and the challenges they face. The data collection process involved recording various details for each street tree, including the species name, and counting the number of street trees on both the street sides and the median.

To identify the challenges faced by street trees, the method by (Nagendra and Gopal, 2010)was used. They utilized a spatially distributed sampling approach. Following these techniques to identify the challenge, random points were selected along transect of 200 to 500 meters in length by randomly selecting points along this transect.

## 3.7. Sampling Techniques

The study was evaluating the condition of urban street trees and assess their ecosystem services provision. To achieve this, the researcher used a sampling technique based on the study's objectives, the need to access specific data, and personal experience. Key informant interviews were conducted using **purposive sampling** to gather information from officials and experts involved in urban greenery, sanitation, and beautification. Questionnaires were distributed using **simple random sampling** for data collection from different street user who passed through the street during the survey period by considering right and left walkway. **Spatially distributed sampling** was employed to survey street trees, collecting data on each tree's species, spacing between trees, and any challenges they faced.

### 3.7.1 Criteria's for Selecting Study Segments

To achieve the intended objectives, a first preliminary survey was made to understand the overall condition of the street tree to identify ecosystem supply and demand to select the appropriate study sites. Moreover, the research was conducted around different areas of Hawassa, and the case selection was characterized by having, **land use, street hierarchy and user traffic flow**. The sampling sites were categorized into five different streets. The three streets were from the inner-city zone and the other two from peripheral zone.

*Table 3.1 Existing Street design*

| Street Name | Total Width (M) | Length of the street | Number of Carriage Ways | Width of each Carriage Way (m) | Width of Median (m) | Width of right Pedestrian Walkway (m) | Width of left Pedestrian Walkway (m) | Street tree green space in the walkway |
|---|---|---|---|---|---|---|---|---|
| Tesfaye Gizaw to | 20 | 1.16 km | 2 | 10 | 1.5 | 2 | 2 | 4-4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Atote meberat | | | | | | | | |
| Tabour primary school to Hawassa university college of agriculture | 6 | 813 m | 1 | 3 | --- | 1.5 | 1.5 | 2-2 |
| Hawassa main university to Hawassa textile | 30 | 3.65km | 2 | 12 | 1.5 | 2.5 | 2.5 | 35-8 |
| south star hotel to wanza | 30 | 1.02 km | 2 | 10 | 2 | 3 | 3 | 8-10 |
| St. Gabriel church to Fikir lake | 30 | 1.48 km | 2 | 10 | 1.5 | 2 | 2 | 6-7 |

*Source: Author*

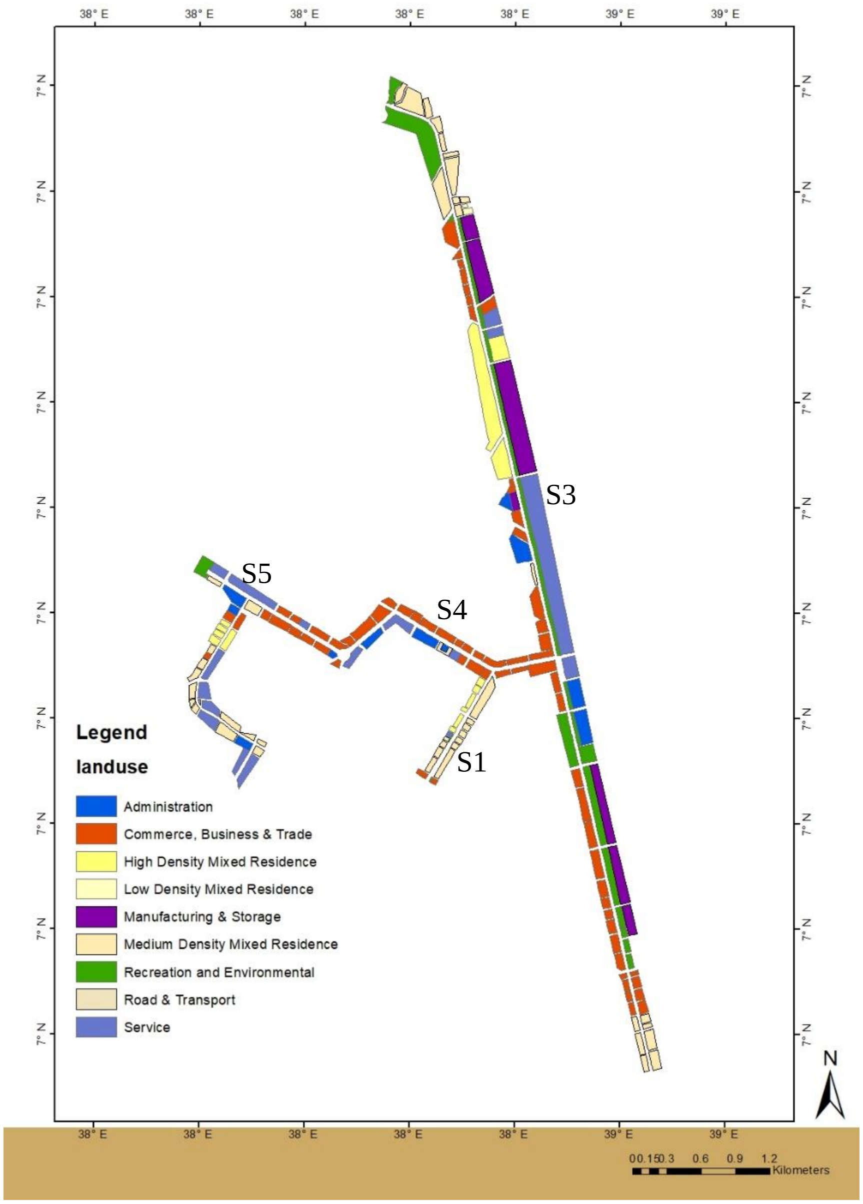
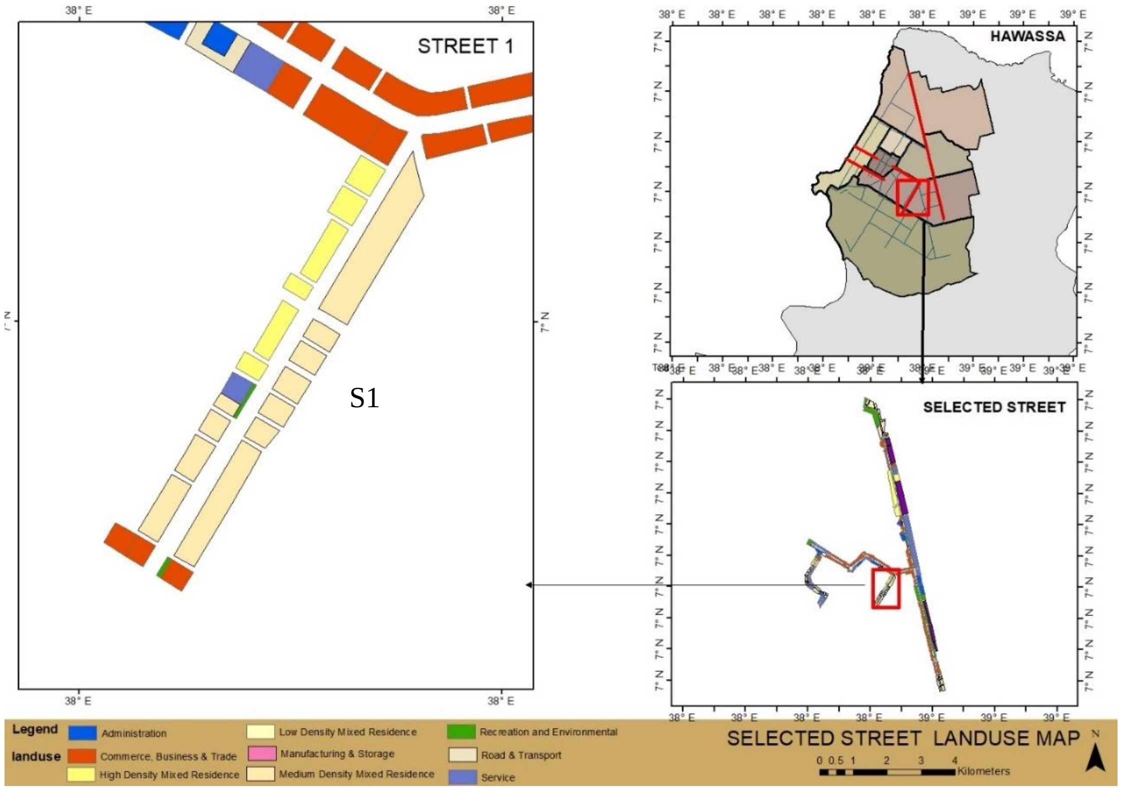


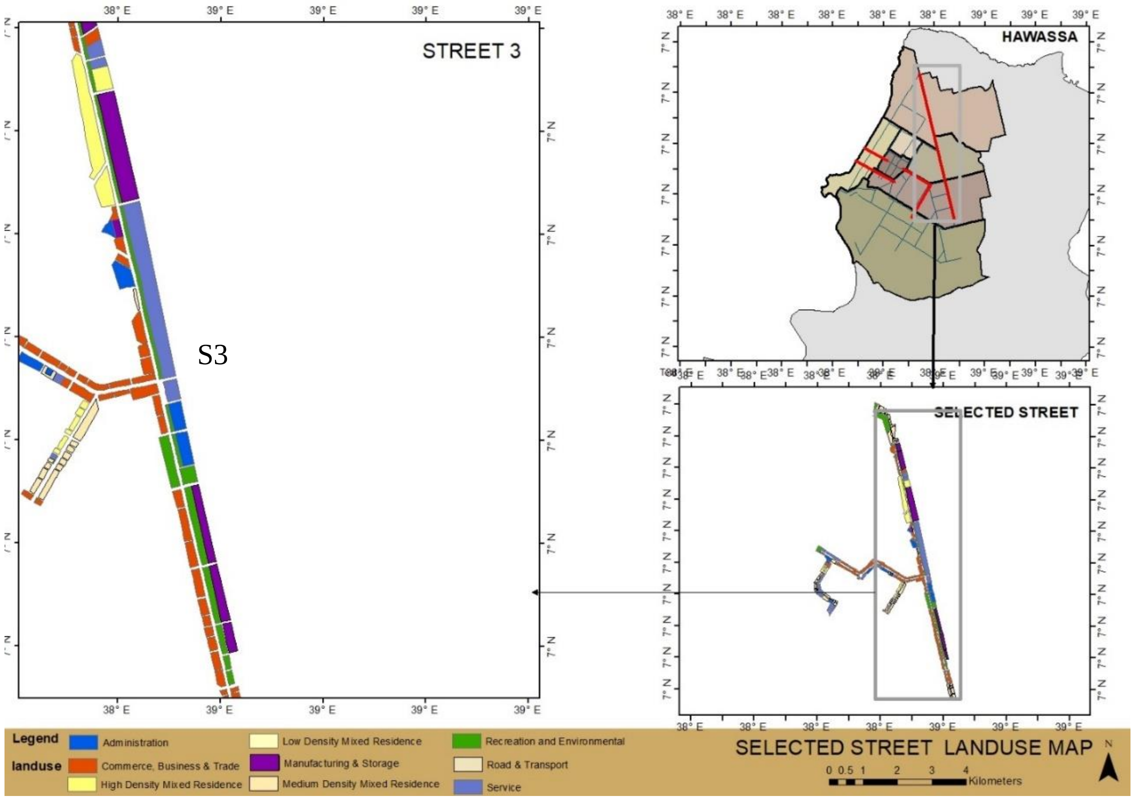

*Figure 3.1 Land use map*

**Street 1:** street segment from **Tesfaye Gizaw to Atote meberat;** this site was selected based on a variety of factors, including its quality, land use, and activity mix, including services and public use but most importantly residential district. Variety of species also lives in its sideways and median tree.

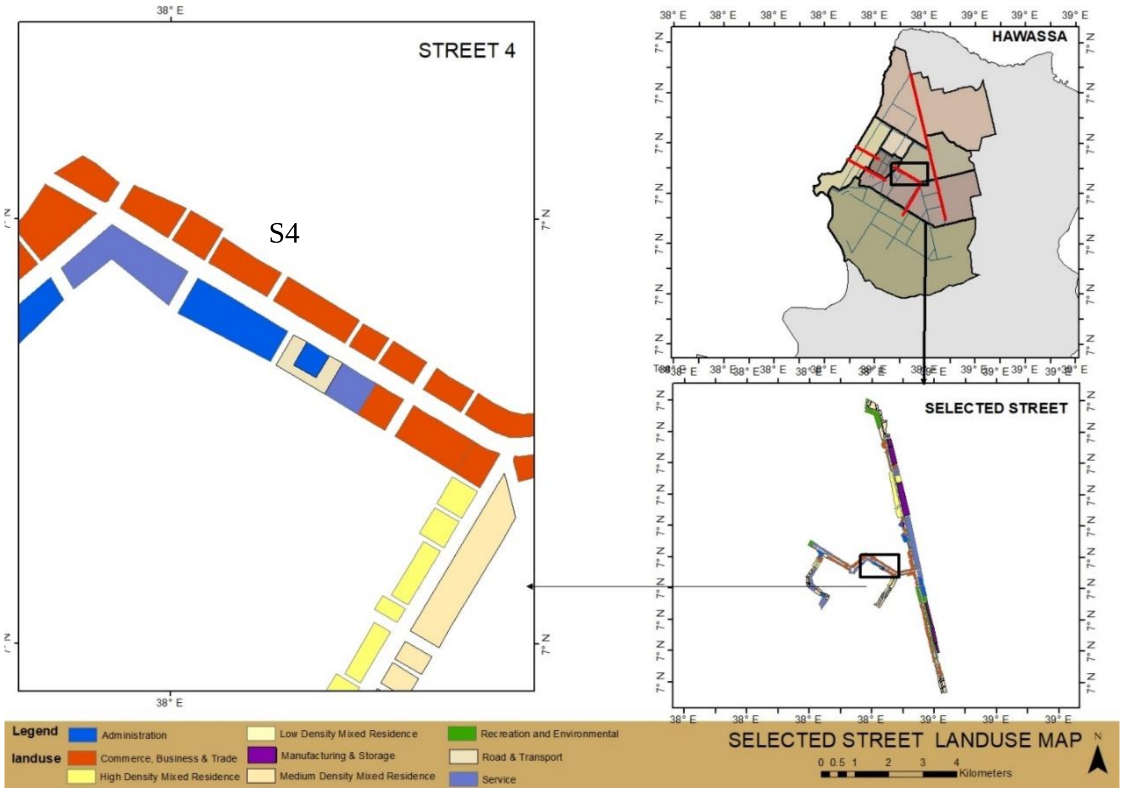



**Street 2:** Street segment Tabor Primary School to Hawassa Agricultural College. Site requirements are based on a mix of land uses, with residential as the primary purpose, including institutional and commercial uses. Compared to other selected streets, user traffic is low, but pedestrian flow is good both during the day and at night and LS street hierarchy type.

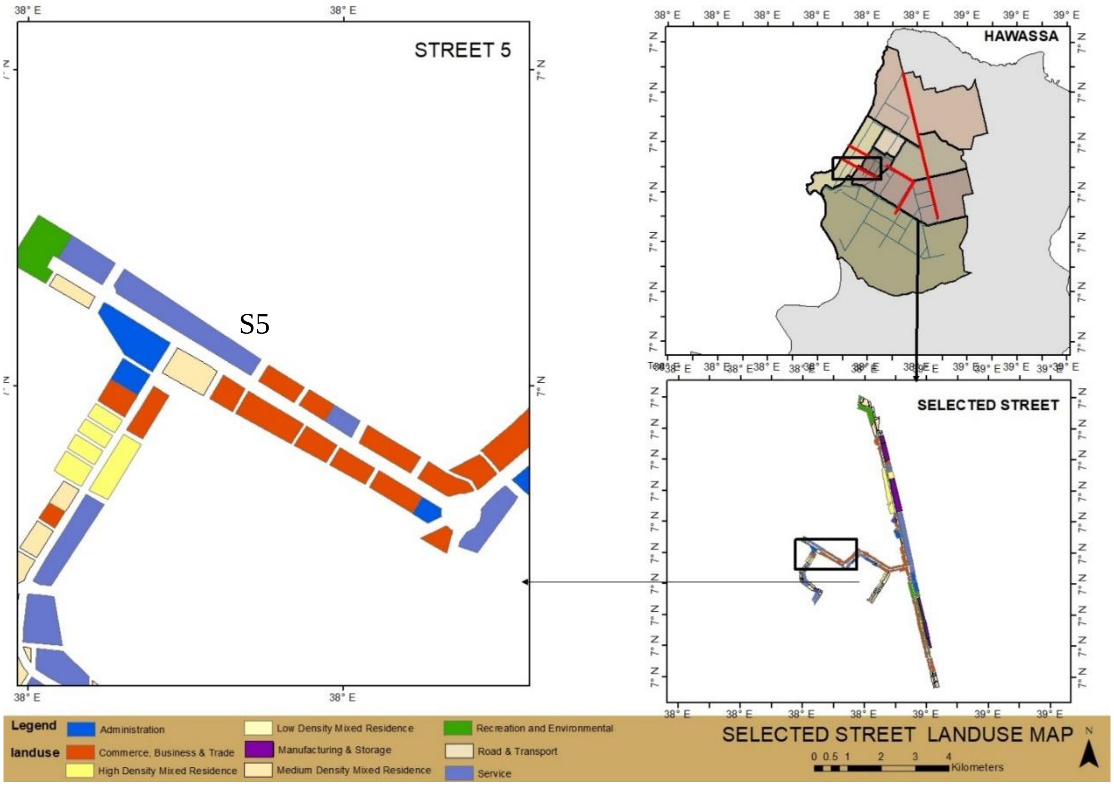
**Street 3:** Street segment from **Hawassa University Main Campus to Hawassa textile.** This location was selected based on a variety of factors, including its mixed land uses. But particularly its school and industrial districts, medium levels of pedestrian traffic, rich species composition and the other one road type that means urban motorway type support different activity and experience compared to other streets.




**Street 4: S**treet segment from **South Star Hotel to Wanza**. This site was chosen on a variety of factors, including its quality mixed land use which include commercial, service land use with high human traffic flow and PAS street hierarchy type.




**Street 5**: Street segment from **St. Gabriel church to Fikir Lake.** This site was selected based on different quality that the site contains different land use activity but the major one is commercial, service and recreational district and is central part of the Hawassa city that held different program and event activities in the street, high traffic flow in terms of pedestrian flow rather than the other selected street in addition to this criteria availability of different species with mature high trees.




## 3.8. Method of Data Analysis and Presentation

### 3.8.1. Method of Data Analysis

Both quantitative and qualitative techniques were used to analyze the data. The data collected through observations, key informant interviews and questionnaires were analyzed using quantitative methods to interpret evidence through discussion and narration. The data collected through the survey questionnaire in the field using the Kobo Collect tool on mobile devices was initially coded. The collected data was then transferred to Microsoft Excel for organization before being imported into SPSS 27 software for statistical analysis.

### 3.8.2. Method of Data Presentation

The study employed a variety of software tools to effectively present and analyze the data. Microsoft Excel and Microsoft Word were utilized for data organization and documentation purposes. Simple graphics, including maps, pictures, tables, and 3D images, were also created to visually represent the findings. ArcGIS and Google Maps were used to generate location maps and to indicate specific selected street locations.

IBM SPSS Statistics 27 was employed for statistical analysis of the data. Additionally, various design and visualization software tools were utilized to improve the presentation of the research results. For instance, Adobe Photoshop was used to generate map presentations, AutoCAD was utilized for creating 2D maps, and Revit and Lumion were employed to develop detailed 3D models and renderings.

*Table 3.2 Summary of the research methodology*

| Research questions | Data Type | Data Sources | Sampling Methods | Data Collection Techniques | Method of Data Analysis |
|---|---|---|---|---|---|
| What is the existing street tree species type and streetscape element in Hawassa | Primary | Field survey street user (pedestrian, cyclist, vendors, storefronts, car user) | Spatially distribute sampling and simple random sampling | Observation Field survey Questionnaire | Both: Qualitative & Quantitative |

| | | | | | |
|---|---|---|---|---|---|
| What is the challenge of street tree development and management in Hawassa? | Primary & secondary data | -Hawassa city development and construction Bureau (city beautification and urban greenery development )<br>-Municipality service standard expert Hawassa infrastructure and construction office Bureau<br>-Governmental project design and construction<br>-survey (street tree) | Purposive sampling | Key informant Interview and Observation | Qualitative |
| What are supply and demands of ecosystem provision from urban street trees in Hawassa? | Primary &secondary Data | Street user (pedestrian, cyclist, vendors, storefronts, car user) | Simple random sampling | Questionnaire and Observation | Qualitative |

# Chapter Four: Results and Discussion

## 4.1 Results

### 4.1.1 Respondent Characteristics

The survey categorized respondents based on their age, gender, occupation, type of respondent, and level of education to address the different community groups and to identify patterns and differences in perceptions and behaviors among them.

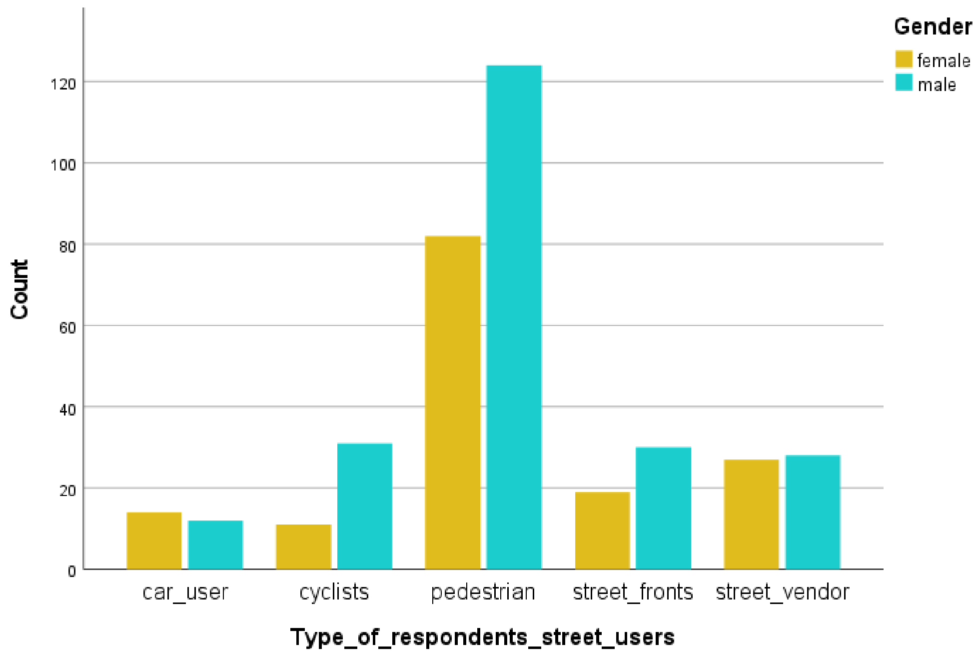



*Figure 4.1 Gender group characterized by respondent type.*

The survey included a total of 378 participants, with 59.5% of them being male and 40.5% being female. The highest numbers of respondents were male, according to (Figure 4.1).

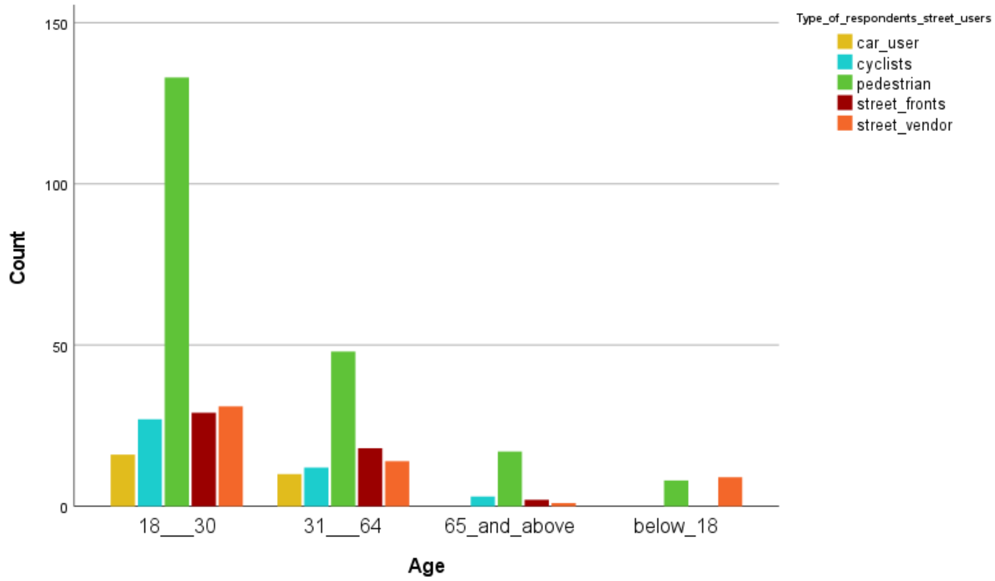



*Figure 4.2 Age range characterized by respondent type.*

According to the survey results, 4.5% of the respondents were under the age of 18, while the majority (62.4%) was between the ages of 18 and 30. In addition, 27.0% of the respondents were between the ages of 31 and 64, and 6.1% were 65 years and older. In terms of the type of respondent, 6.9% of the respondents described being car users, 11.1% described being cyclists, and the majority of respondents (54.5%) described being pedestrians. About 13% of respondents described being street fronts, while 14.6% described being street vendors (Figure 4.2).

*Table 4.1 Educational status characterized by occupation.*

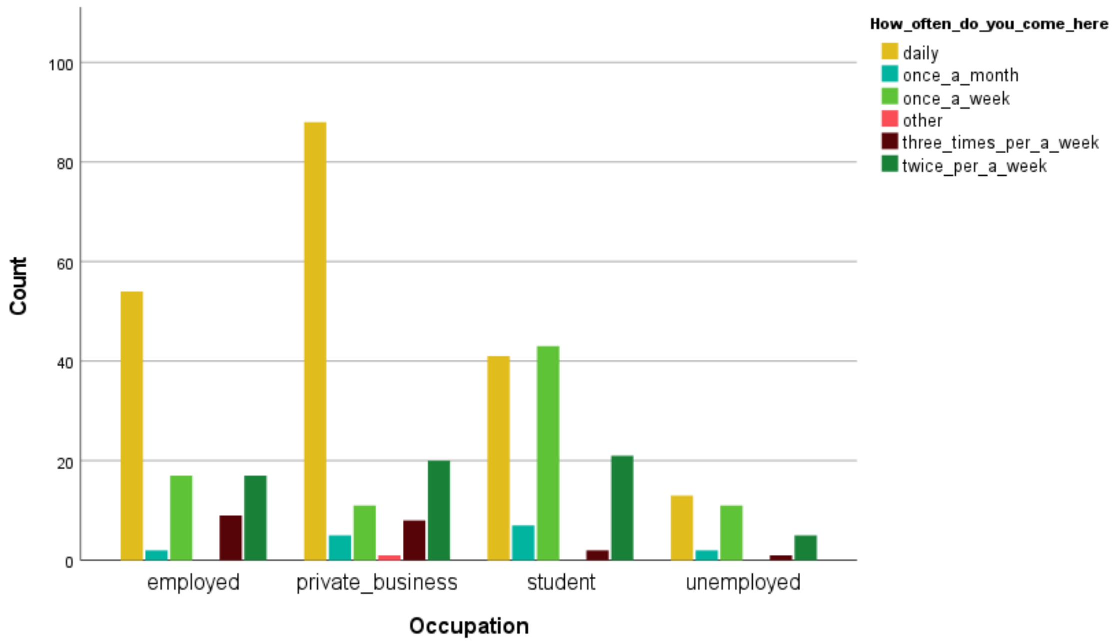
| Educational Status | Occupation | | | | Total |
|---|---|---|---|---|---|
| | employed | Private business | student | unemployed | |
| No educational Status | 11 | 62 | 0 | 11 | 84 |
| Primary school (1-8) | 5 | 18 | 5 | 2 | 30 |

| | | | | | |
|---|---|---|---|---|---|
| secondary school (9-12) | 3 | 5 | 23 | 3 | 34 |
| Certificate diploma | 29 | 25 | 18 | 9 | 81 |
| Degree | 38 | 20 | 53 | 6 | 117 |
| Master's and above | 13 | 3 | 15 | 1 | 32 |
| Total | 99 | 133 | 114 | 32 | 378 |

The information collected from the survey on the respondents' occupation and educational Status showed that 26.2% of the respondents were employed, 35.2% were private business owners, 30.2% were students, and 8.5% were unemployed. In terms of educational background, the highest number of respondents (31%) had a degree, followed by 21.4% with a certificate diploma, 9% with secondary school education (9-12), and 7.9% with primary school education (1-8). Additionally, 8.5% of the respondents had a master's degree or higher, while 22.2% had no educational Status (Table 4.1).

*Table 4.2 occupation characterized by frequency of coming.*

| Occupation | Daily | Twice per a week | Three times per a week | Once a week | Once a month | other | Total |
|---|---|---|---|---|---|---|---|
| Employed | 54 | 17 | 9 | 17 | 2 | 0 | 99 |
| Private Business | 88 | 20 | 8 | 11 | 5 | 1 | 133 |
| Student | 41 | 21 | 2 | 43 | 7 | 0 | 114 |
| Unemployed | 13 | 5 | 1 | 11 | 2 | 0 | 32 |
| Total | 196 | 63 | 20 | 82 | 16 | 1 | 378 |




The survey also collected information on how frequently participants accessed the surveyed street segments. Results showed that the highest number of respondents (51.85%) accessed the streets daily, while 21.69% accessed the streets once a week and 16.67% accessed the streets twice per week. Smaller percentage of respondents reported accessing the streets three times per week (5.29%), once a month (4.23%), or occasionally (0.26%). Overall, most respondents accessed the surveyed street segments on a regular basis, with daily access being the most common (Table 4.2).

*Table 4.3 purpose of coming.*

| Purpose of coming | | |
|---|---|---|
| Value | Frequency | Percentage |
| Work/business | 222 | 58.7 |
| Recreation /visiting | 97 | 25.7 |
| Walking | 93 | 24.6 |
| Shopping | 84 | 22.2 |
| Family | 45 | 11.9 |
| Education | 44 | 11.6 |

| | | |
|---|---|---|
| Appointment | 40 | 10.6 |
| Other | 17 | 4.5 |
| Total | 642 | 169.8% |

The information collected on the reasons why participants accessed the surveyed street segments showed that the majority of respondents (58.73%) reported accessing the streets for work and business, while 25.66% accessed the streets for recreation and visit, and 24.6% for walking. Shopping was reported as the reason for accessing the streets by 22.22% of respondents, and 11.9% reported accessing the streets for family visits. Additionally, 11.64% of respondents accessed the streets for educational purposes, while 10.58% accessed the streets for appointments. A small percentage (4.5%) reported accessing the streets for other reasons, such as church visits. Overall, the results indicated that the primary reason for accessing the surveyed street segments was for work and business purposes (Table 4.3).

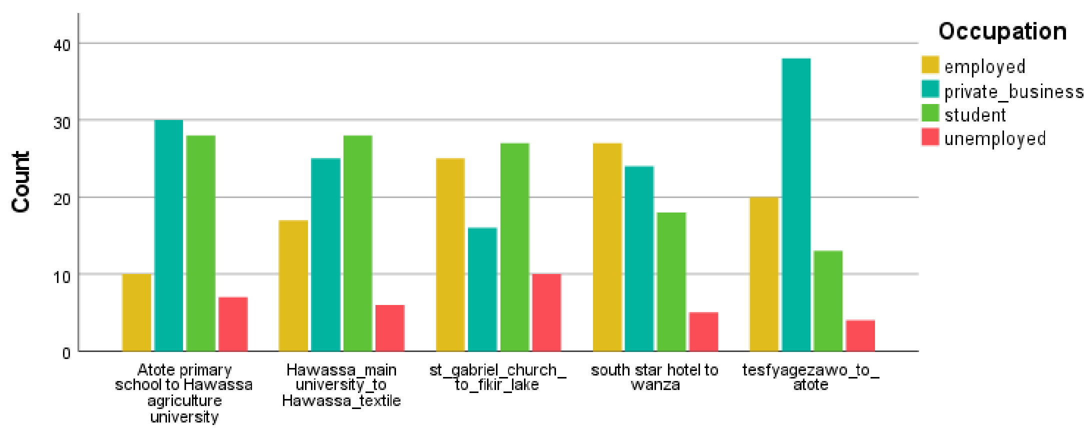



*Figure 4.3 Street segment characterized by study area type.*

Among participants, about 75 (19.5%) were selected at Tabor primary school to Hawassa agricultural college. The highest number of private business respondents had been surveyed, and 76( 20.1%) were selected at Hawassa university main campus to Hawassa textile with the highest number of student respondents has been surveyed, 78(20.6%) were selected at St Gabriel church to fikir lake with the highest number of student respondents had been surveyed, 74(19.6 %) were selected at south star hotel to wanza with the highest number of employed respondents has been surveyed and 75 (19.8 %) were selected at Tesfaye Gizaw to Atote meberat with the highest number of private business respondents has been surveyed (Figure 4.3).

### 4.1.2 Existing Street tree species type and streetscape element

According to the study, the percentage of indigenous tree species along the five streets were between 21% and 33%, while the percentage of exotic tree species ranged between 66% and 82%. The five studied streets were covered with a dense canopy of trees, with a total of 1588 mature trees, representing 37 species and 22 families, and 665 sapling trees, representing 13 species and 11 families.

*Table 4.4 Diversity of tree species along selected street segment*

| No | Street | Tree species | | Proportion of indigenous tree as % |
|---|---|---|---|---|
| | | Exotic | Indigenous | |
| 1 | Tesfaye Gizaw to Atote meberat | 16 | 7 | 30.43% |
| 2 | Tabor primary school to Hawassa agricultural college | 14 | 3 | 17.65% |
| 3 | Hawassa university main campus to Hawassa textile | 10 | 5 | 33.33% |
| 4 | South star hotel to wanza | 15 | 4 | 21% |
| 5 | St .Gabriel church to fikir lake | 16 | 6 | 27.3% |

### Tesfaye Gizaw to Atote meberat

From Tesfaye Gizaw to Atote mebrat, a total of 294 street trees were identified, comprising 23 species and 18 families (Appendix B). Out of these 69.57% were exotic and the rest 30.43% indigenous (Table 4.4). Evergreen trees were the dominant leaf phenology (87%), while 13% were Deciduous (Table 4.5). The most abundant species based on right side walkway, median and left side walkway street tree (Figure 4.4) were *Callistemon citrinus* (25.61%), *Araucaria biramulata* (50.65%) and *Grevillea robusta* (22.47%), respectively.

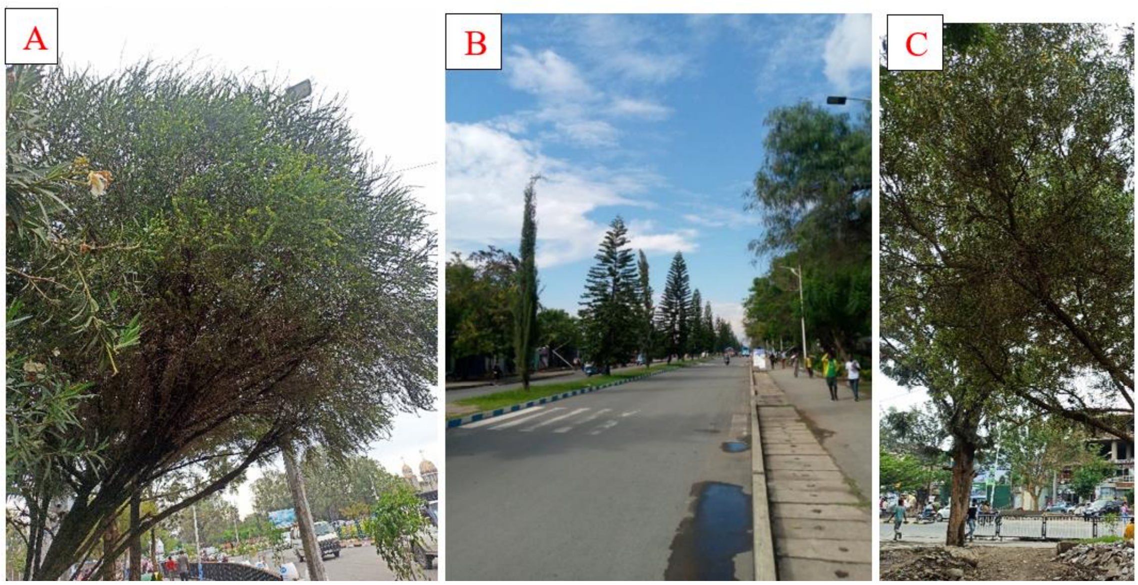



Figure 4.4 Images of the most abundant species from street trees at Tesfaye Gizaw to Atote meberat (**A**–**C**).*(**a**) Callistemon citrinus (right side) ; (b) Araucaria biramulata (media );(c) Grevillea robusta (left side) (Source: Author, 2023)*

### Tabor primary school to Hawassa agricultural college

From Tabor primary school to Hawassa agriculture university a total of 165 street trees were identified, which comprises 17 species and 12 families in (Appendix C) out of which 82.35% were exotic and the rest 17.65% indigenous (Table 4.4). Evergreen trees were the dominant leaf phenology 76.5%, while (23.5%), were Deciduous (Table 4.5). The most abundant species based on right side walk way street tree and left side walk way tree (Figure 4.5) were *Grevillea robusta* (55.75%) and *Grevillea robusta* (54.55%), are distributed widely in the street segments respectively.


Figure 4.5 Images of the most abundant species from street trees from Tabor primary school to Hawassa Agricultural College (*a–b*). *(a) Grevillea robusta (right side; (**b**) Grevillea robusta (left side)* *(Source: Author, 2023)*

**Hawassa University main campus to Hawassa textile**

A total of 904 street trees were identified, comprising 16 species and 13 families (Appendix D) out of which 66.67% were exotic and the rest 33.33% were indigenous (Table 4.4). Evergreen trees were the dominant leaf phenology (81.25%), whereas 18.75% were Deciduous (Table 4.5). The most abundant species based on right side walk way, median and left side walk way street tree (Figure 4.6) were *Croton sylvaticus* (28.21%), *Ficus benjamina* (41.94%) and *Grevillea robusta* (80.55%) respectively.


Figure 4.6 Images of the most abundant species from street trees at Hawassa university main campus to Hawassa textile (A–C). *(a) Croton sylvaticus (right side) ; (b) Ficus benjamina (media );(c) Grevillea robusta (left side) (Source: Author, 2023)*

**South star hotel to Wanza**

From south star hotel to wanza a total of 382 street trees were identified. These trees belonged to 19 species and 15 families (Appendix E), out of which 79% were exotic and the rest 21% indigenous (Table 4.4). Evergreen trees were the dominant leaf phenology (78.95%) while 21.05% were Deciduous (Table 4.5). The most abundant species based on right side walk way, median and left side walk way street tree (Figure 4.7) were *Senna marilandica* (29.36%), *Phoenix reclinate* (82.14%) and *Grevillea robusta* (43.16%) respectively.

*Figure 4.7 Images of the most abundant species from street trees at south star hotel to wanza (A–C). (a) Senna marilandica? (right side) ; (b) Phoenix reclinate (media );(c) Grevillea robusta (left side) (Source: Author, 2023)*

### St .Gabriel church to Fikir Lake

From St .Gabriel church to Fikir Lake a total of 508 street trees were identified. It comprised 22 species and 18 families (Appendix F) out of which 72.7% were exotic and the rest 27.3% were indigenous (Table 4.4). Evergreen trees were the dominant leaf phenology (86.36%), while 13.64% were Deciduous (Table 4.5). The most abundant species based on right side walkway, median and left side walkway street tree (Figure 4.8) were *Jacaranda mimosifolia* (39.80%), *Phoenix reclinate* (62.98%) and *Terminalia brownii* (25.64%).


*Figure 4.8 Images of the most abundant species from street trees at St .Gabriel church to fikir lake (A–**C**).(**a**) Jacaranda mimosifolia (right side) ; (b) Phoenix reclinate (media );(c) Terminalia brownii (left side) (Source: Author, 2023)*

*Table 4.5 Diversity of tree Origin (deciduous or evergreen tree) along selected street segment*

| No | Street | Origin | | Proportion of Deciduous tree as % |
|---|---|---|---|---|
| | | Evergreen | Deciduous | |

| | | | | |
|---|---|---|---|---|
| 1 | Tesfaye Gizaw to Atote meberat | 20 | 3 | 13% |
| 2 | Tabor primary school to Hawassa agricultural college | 13 | 4 | 23.5% |
| 3 | Hawassa university main campus to Hawassa textile | 13 | 3 | 18.75% |
| 4 | South star hotel to wanza | 15 | 4 | 21.05% |
| 5 | St .Gabriel church to fikir lake | 19 | 3 | 13.64% |

This outcome has indicated that the proportion of evergreen plants is higher than that of deciduous plants, providing shade throughout the year. However, street structure characteristics posed a challenge, such as problems with mature size, unstable branches, and unclear trunk height from the ground. These factors can make it risky to use the sidewalk under the tree. In addition, some species, like (*Terminalia brownii*), exhibit overgrowth patterns and forms that can further complicate the situation. Furthermore, trees planted in narrow boulevards are susceptible to conflicts with sidewalks and streets as their roots grow. This issue is compounded by the wrong selection of tree species due to the selection criteria that prioritize flower color and attractive morphology while neglecting other critical characteristics such as poisonous nature, (e.g. *Nerium oleander*) (Figure 4.9).


Figure 4.9 characteristics of street tree structure challenge

**Street scape element**

*Table 4.6 street scape element assessment from each five street*

| Street scape element | | Street 1 Mean | Street 2 Mean | Street 3 Mean | Street 4 Mean | Street 5 Mean |
|---|---|---|---|---|---|---|
| Street tree | Sidewalk tree | 3.37 | 3.60 | 3.18 | 3.77 | 3.64 |
| | Median tree | 3.69 | 1.04 | 2.41 | 3.58 | 3.85 |
| | Flower stands | 1.27 | 1.04 | 1.46 | 1.72 | 2.45 |
| Street lighting | Street lighting system | 3.72 | 1.44 | 4.24 | 4.04 | 3.82 |
| | Safety and security | 3.28 | 1.40 | 3.07 | 3.12 | 3.49 |
| Street furniture | Parking | 1.60 | 1.12 | 2.13 | 2.14 | 2.08 |
| | Benches | 1.48 | 1.04 | 1.51 | 2.95 | 3.03 |
| | Signage | 1.75 | 1.04 | 2.34 | 2.28 | 2.60 |
| | Trash can | 1.25 | 1.03 | 1.53 | 1.66 | 2.77 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Bicycle racks | Bicycle line | 1.08 | 1.11 | 1.07 | 1.42 | 1.56 |
| | Bicycle parking | 1.05 | 1.07 | 1.32 | 1.62 | 1.71 |
| Pavement | Perforation pavement | 1.59 | 1.88 | 1.83 | 2.43 | 2.33 |
| | Comfortable for use | 3.43 | 2.64 | 3.01 | 3.70 | 3.63 |

**Note**: the five-point Likert scale is considered as an interval scale. The mean is very significant.

*Table 4.7 The five-point Likert scale is considered an interval scale.*

| Likert scale | scale | interval length | lower limit | upper limit | interval |
|---|---|---|---|---|---|
| very poor | 1 | 0.8 | 1 | 1.80 | (1:1.80) |
| Poor | 2 | 0.8 | 1.81 | 2.6 | (1.81:2.60) |
| medium | 3 | 0.8 | 2.61 | 3.40 | (2.61:3.40) |
| good | 4 | 0.8 | 3.41 | 4.20 | (3.41:4.20) |
| very good | 5 | 0.8 | 4.21 | 5 | (4.21:5) |

As shown in (Table 4.6) the study assessed the availability of streetscape elements in five different streets using a five-category approach, including street trees, street lighting, street furniture, bicycle racks, and pavement.

For Street 1, the availability of sidewalk trees was perceived to be on a medium scale with a mean value of 3.37. Median trees were perceived to be in good condition with a mean value of 3.69, while flower stands were perceived to be in very poor condition with a mean value of 1.27. The availability of the street lighting system and feeling safety and security was perceived to be in good and medium condition with a mean value of 3.72 and 3.28 respectively. Street furniture, bicycle racks, and pavement were perceived to be in very poor condition, except for comfortable pavements, which were perceived to be in good condition with a mean value of 3.43.

For Street 2, sidewalk trees were perceived to be in good condition with a mean value of 3.60. Perforation pavement and comfortable movement were perceived to be on poor and medium scales, respectively, with mean values of 1.88 and 2.64. The availability of street lighting systems, street furniture, bicycle racks, were perceived to be in very poor condition with mean values less than 1.44.

For Street 3, sidewalk trees were perceived to be in medium condition with a mean value of 3.18, while media trees were perceived to be in poor condition with a mean value of 2.41. Flower stands were perceived to be in very poor condition with a mean value of 1.46. The street lighting system was observed to be in very good condition with a mean value of 4.24, while safety and security were perceived to be in medium condition with a mean value of 3.07. the availability of street furniture and pavement such as parking, benches, signage, and trash cans, and bicycle-related infrastructure such as bicycle lines and bicycle parking, perforation pavement and comfortable for movement, were generally perceived to be in very poor to medium condition with mean value respectively: 2.13, 1.51, 2.34,1.53, 1.07, 1.32, and 1.83, 3.01

For Street 4, sidewalk trees and median trees were perceived to be in good condition with mean values of 3.77 and 3.58, respectively. Flower stands were perceived to be in very poor condition with a mean value of 1.72. The street lighting system was perceived to be in good condition with a mean value of 4.04, while safety and security were perceived to be in medium condition with a mean value of 3.12. Street furniture and pavement were perceived as follows; Parking, benches, signage, trash cans, bicycle line, bicycle parking, and perforation pavement values: 2.14,2.95, 2.28, 1.66, 1.42, 1.62, and 2.43, respectively (very poor scale to medium scale) and comfortable for movement: 3.7 (good scale).

For Street 5, sidewalk trees and median trees were perceived to be in good condition with mean values of 3.64 and 3.85, respectively. Flower stands were perceived to be in poor condition with a mean value of 2.45. Street lighting systems and safety and security were perceived to be in good condition with mean values of 3.82 and 3.49, respectively. Finally, the availability of street furniture and pavement such as parking, benches, signage, and trash cans, and bicycle-related infrastructure such as bicycle lines and bicycle parking, perforation pavement, were generally perceived to be in very poor to medium condition with mean value respectively 2.08,3.03, 2.60, 2.77, 1.56, 1.71, and 2.33 and Comfortable for movement: 3.63 (good scale)

The use of a five-category approach provides a comprehensive means of evaluating the status of streetscape elements and identifying areas for improvement.

*Table 4.8 finding of streetscape element overall.*

| Streetscape element | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Street tree | Sidewalk tree | 378 | 3.51 | .799 |
| | Median tree | 378 | 2.92 | 1.305 |
| | Flower stands | 378 | 1.59 | .909 |
| Street lighting | Street lighting system | 378 | 3.46 | 1.317 |
| | Safety and security | 378 | 2.88 | 1.151 |
| Street furniture | Parking | 378 | 1.81 | 1.005 |
| | Benches | 378 | 2.01 | 1.147 |
| | Signage | 378 | 2.01 | 1.047 |
| | Trash can | 377 | 1.65 | .961 |
| Bicycle racks | Bicycle line | 378 | 1.25 | .636 |
| | Bicycle parking | 378 | 1.35 | .711 |

| | | | | |
|---|---|---|---|---|
| Pavement | Perforation pavement | 378 | 2.01 | .934 |
| | Comfortable for use | 378 | 3.28 | .937 |

As shown in (Table 4.8), the streetscape element assessed to rate the availability of streetscape by including five different categories were; street tree, street lighting, street furniture, bicycle racks and pavement. In the street tree, the highest mean value is 3.51, showed that most participants responded the availability of sidewalk tree at good scale. The highest mean value of the second statement (street lighting) was 3.46. Accordingly, the majority of respondent believe that the availability of median tree is in medium scale. The third statement was about Street furniture that included four different categories; from these, the majority of respondents have believed that the availability Benches and signage with equal mean value (2.01) is in poor condition which is better than parking and trash can. The fourth statement under bicycle racks that include two different categories; bicycle line and bicycle parking, the mean values are (1.25) and (1.35) respectively showed both were responded in very poor condition.

Finally, the fifth statement is about pavement that include pavement perforation and comfortable for use. The highest mean value of this statement (pavement) is 3.28. Accordingly, the majority of respondent believed that the availability of comfort for use is in medium scale.

**Observation checklist from streetscape**

*Table 4.9 Findings from observation checklist*

| Streetscape element | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Street tree | Trees indigenous VS exotic | 26 | 2.88 | 1.071 |

| | | | | |
|---|---|---|---|---|
| | Plant diversity | 26 | 2.77 | .992 |
| | Median tree | 26 | 2.35 | 1.164 |
| | Flower stands | 26 | 1.62 | .804 |
| | Space allocation | 26 | 2.50 | 1.140 |
| | Planting location | 26 | 2.69 | 1.350 |
| | Spacing between trees_ | 26 | 2.23 | 1.107 |
| Street lighting | Street lighting system | 26 | 3.58 | 1.474 |
| | Safety and security | 26 | 3.15 | 1.008 |
| Street furniture | benches | 26 | 2.12 | 1.275 |
| | signage | 26 | 1.69 | .788 |
| | Trashcans | 26 | 1.54 | .948 |
| Bicycle racks | Bicycle line | 26 | 1.15 | .368 |
| | Bicycle parking | 26 | 1.62 | .941 |
| Pavement | Perforation pavement | 26 | 2.46 | .859 |
| | Comfortable for use | 26 | 3.27 | .962 |

Based on personal observations, the different categories of street scape have been rated on various parameters, and the mean values for each parameter are as follows: Trees indigenous vs. exotic value: 2.88 (medium level), Plant diversity: 2.77 (medium scale), Availability of median tree: 2.35 (poor scale), Flower stands: 1.62 (very poor scale), Space allocation: 2.69 (medium scale), Spacing between trees: 2.23 (poor scale), Street lighting system: 3.58 (good), Safety and security: 3.15 (medium scale), Benches, signage, trash cans, bicycle line, bicycle parking, and perforation pavement values: 2.12, 1.69, 1.54, 1.15, 1.62, and 2.46, respectively (very poor to poor scale), Comfortable for movement: 3.27 (medium scale) .In summary, the ratings have indicated that the proportion of indigenous and exotic trees is dispersed at a medium level, while the availability of flower stands, benches, signage, trash cans, bicycle lane, bicycle parking, and perforation pavement is very poor. Most of the sidewalk trees are unplanned, and the spacing between trees is poor. However, the availability of street lighting is good, and the safety and security are at a medium scale. The area is also moderately comfortable for movement (Table 4.9).

Apart from utilizing a questionnaire survey and observation checklist, an interview was also conducted with the Hawassa construction office to discuss street design. The interview focused on the involvement of professionals during the design process and consideration of streetscape elements. Most of the interviewees acknowledged that this factor had been poorly considered during the design phase. However, they mentioned that there had been some progress in the field of streetscape design. The following are some expert from the responses that highlight the integration challenges:

> “For instance, a project has been initiated from the South Star Hotel to Wanza to reconstruct the road while considering siting, lighting and trash can by incorporating pedestrian accessibility, however for other street is there is no practice regarding streetscape element.’’

> “The road designs fail to consider the human scale since they are not influenced by urban design, landscape design, or other relevant professions. Globally, streetscape design goes beyond traffic design and primarily focuses on creating open public spaces and informal pathways that facilitate the provision of street trees along the street.”

> “During the design of the new high-speed road, an intelligent and old tree was saved from removal. However, there was no cooperation with other organizations to consider how the tree could be integrated into the overall design of the area. As a result, the tree's contribution to the aesthetic and ecological value of the surroundings may not have been fully realized. While preserving the tree was a positive step, the lack of collaboration with other institutions limited its potential to enhance the overall streetscape design.”

> "The reason why greenery is not considered in road design is due to a lack of integration."

The responses outlined above have indicated that the inadequate development of street tree planting with the integration of streetscape design for ecosystem services is a significant concern in the city. In addition to design issues, there is also a problem with professional integration. Respondents claim that there are no landscape architects or professionals specifically related to street tree planting during road construction. Instead, spaces are allocated for planting without considering the planting habits of trees. Furthermore, after the design is implemented, street tree planting workers often plant trees without knowing the location of water or electric lines, leading to conflicts with the infrastructure.

### 4.1.3 Challenges of Street Tree Development & Management

**Challenge of street tree management**

*Table 4.10 challenge of street tree management*

| challenge | | |
|---|---|---|
| Challenge from urban street trees | N | Percent of Cases |
| Tree branch falling and littering | 171 | 45.20% |
| Ugly trees with low maintenance level | 32 | 8.50% |
| Blocking view | 35 | 9.30% |
| Causing drainage problems | 11 | 2.90% |
| Damage to property buildings and cars | 45 | 11.90% |
| Obstructing use of space | 29 | 7.70% |
| Hiding traffic signs and lighting | 20 | 5.30% |
| none | 181 | 47.90% |
| other | 5 | 1.30% |

The survey results have revealed several challenges associated with street trees. The most common challenge, identified by 45.20% of respondents was tree branches falling and littering as shown (Figure 4.10). Additionally, 8.50% of respondents reported that they considered some trees to be unsightly due to low maintenance levels, while 9.30% reported that street trees can block views. Other challenges included drainage problems caused by street trees (2.90%), damage to property and vehicles as trees mature (11.90%), obstructing the use of space (7.70%), and hiding traffic signs and lights (5.30%). Interestingly, almost half of the respondents (47.90%) did not perceive any challenges associated with street trees. However, a small percentage of respondents (1.30%) identified other challenges associated with street tree development and management (Table 4.10).


*Figure 4.10 Images of the some challenge from the street tree (**a**–**C**).(**a**) littering (b) wrong species selection with no consideration size of planting pit c) conflict with infrastructure (Source: Author, 2023)*

*Table 4.11 challenge of street tree management*

| challenges of street tree management | | | |
|---|---|---|---|
| | N | Mean | Std. Deviation |
| Tree branch falling and littering | 6 | 4.17 | 1.602 |

| | | | |
|---|---|---|---|
| Ugly trees with low maintenance | 6 | 1.17 | 0.408 |
| blocking view | 6 | 3.17 | 2.041 |
| Conflict with infrastructure | 6 | 4.67 | 0.816 |
| damage to property, building and cars | 6 | 3.67 | 2.066 |
| obstructing use of space | 6 | 2.17 | 1.602 |
| hiding traffic signs and lighting | 6 | 2.83 | 1.835 |
| lack of awareness among users | 6 | 2.33 | 0.816 |
| Finance | 6 | 4.17 | 1.329 |
| lack of skilled experts | 6 | 2.33 | 1.506 |

The survey results have indicated that the most significant challenges related to street trees were street tree littering, failure of whole trees, and conflict with infrastructure. These challenges were rated as high to very high scale by most of the respondents, with mean values of 4.17 and 4.67, respectively. Ugly trees with low maintenance were rated the lowest challenge, with a mean value of 1.17, indicating that most trees were maintained at a good level. Other challenges included blocking views, damage to property and cars, obstructing use of space, hiding traffic signs and lighting and, lack of awareness among users, with mean values ranging from 2.17 to 3.67 which is low, medium, and high scale challenge. Respondents also identified insufficient financial resources as a significant challenge, with a mean value of 4.17. However, the risk and lack of skilled experts were rated as low-scale challenges, with a mean value of 2.33 (Table 4.11). Additionally, respondents identified other major management problems encountered before and after implementation.

We have faced two types of challenges before and after the implementation of street tree. The first challenge was not getting the right plant type to plant in media, not knowing the species use only for the purpose of aesthetics, not well-known species for the first time. Species selection due to ignorance of the mature growth, not to get companion plants in terms of height for example Phoenix reclinate with Terminalia brownii and lastly lack of integration among other institutes respectively.

"There are wrong species tree due to administration involvement and finance allocation reduced for green area development from 90 million birr to 38 million birr."

The development phase presents several challenges, including soil compaction resulting from street paving, a shortage of skilled experts, conflicts with animals, and a lack of awareness and participation from the public.

"There is a lack of integration with other institutes and no to get a companion plant in terms of mature size growth, height and diversity."


*Figure 4.11 General condition of street tree challenge during site survey (Source: Author, 2023)*

**Challenge of street tree development**

*Table 4.12 challenges of street tree development*

| challenges of street tree development | N | Percent |
|---|---|---|
| Wrong species selection | 137 | 36.20% |
| Size of planting pits | 16 | 4.20% |
| Compacted soil conditions | 9 | 2.40% |
| Space allocation | 18 | 4.80% |
| Water availability | 13 | 3.40% |
| Lack of skilled experts | 34 | 9.00% |
| Lack of awareness among users | 33 | 8.70% |
| Finance | 23 | 6.10% |
| None | 190 | 50.30% |
| other | 22 | 5.80% |

As indicated in (Table 4.12), 137(36.20%) of the respondent showed street tree development and management due to wrong species selection and (Figure 4.10) showed 16(4.20%) of the respondent believe that there is a challenge of existing tree size of planting pits. 9(2.40%) of the respondent believes there is compacted soil conditions and 13(3.40%) of the respondent agreed that other management problem is water availability. 34(9.00%) and 33(8.70%) of the respondent selected lack of skilled experts and lack of awareness among users respectively. 23(6.10%) of the respondent selected finance, 190(50.30%) of the participant responded they have not encountered any challenge.

In addition to the survey questionnaire, interviews were made with the Municipality to gain further insight into street tree development challenges. The interviews revealed that the major challenges include inadequate funding and resources, lack of skilled personnel, and a lack of clear policies and guidelines for street tree management as indicated below.

“The major problem of street tree development is basically Outsource service for the purpose of maintenance.”

“The major problem is the management practice and policy implementation.”

“Lack of space (median tree space reduced by building space on a sidewalk) and green space removal for construction and other purpose are the major challenges that we face now a day.”

“The primary reason for the unsuccessful development of street trees is the lack of integration among institutions.”

“There is a rule but not applicable so that every sector work as their wish. Due to the lack of integration is that as one institution completes its work, another begins without considering the impact of its actions on the overall project.

“The major problem of the street development is lack of integration with a concerned organization like Ethio electrical, water authority and telecommunication.”

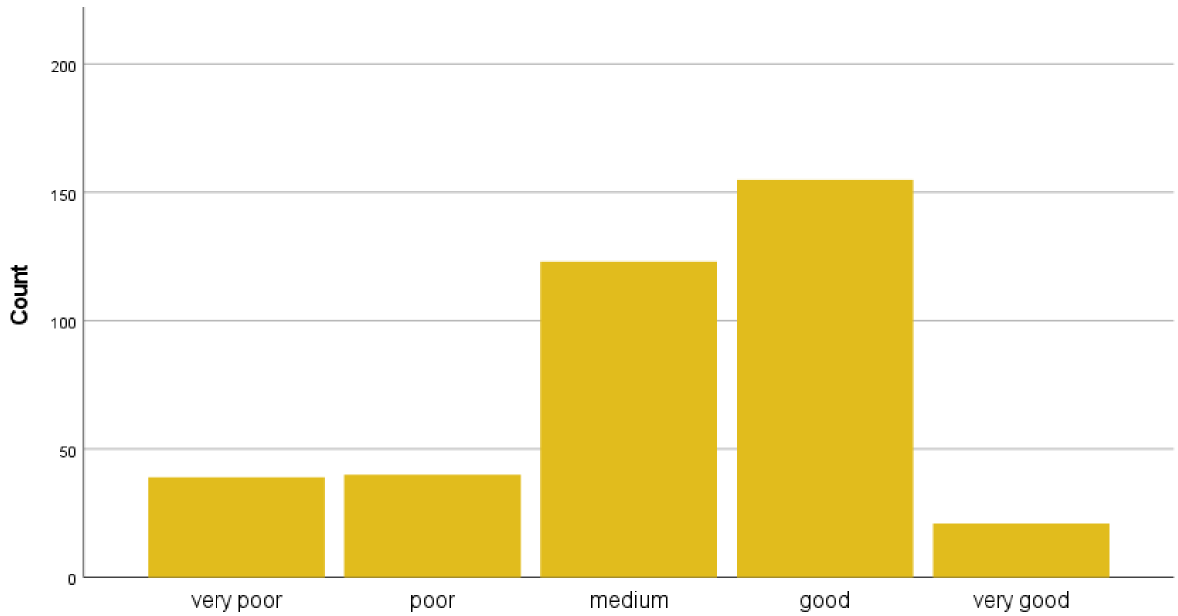



*Figure 4.12 city administration in developing and managing street trees*

The study found that respondents had varying perceptions of the city administration's performance in developing and managing street trees as shown (Figure 4.12) 39(10.3%) of the respondents believe very poor condition. 40(10.6%) of the respondents believe that it is in poor condition. 123(32.5%) of the respondent believe in medium condition. The majority 155(41%) of the respondent believe in good condition and 21(5.6%) believed that the administration's performance was very good.

In addition to the survey questionnaire and observation checklists, interviews with the Municipality clarified on the importance of considering the timing of street tree planting.

*Table 4.13 factor being considered when determining the type of street tree species.*

| What factor being considered when determining the type of street tree species? | | | |
|---|---|---|---|
| | N | Mean | Std. Deviation |
| Large Canopy size | 6 | 3.50 | 1.517 |

| | | | |
|---|---|---|---|
| Aesthetics value | 6 | 5.00 | .000 |
| Stress resistance | 6 | 1.83 | 1.329 |
| Ease of cultivation | 6 | 1.83 | .983 |
| Mass propagation | 6 | 1.83 | .983 |
| Infrastructure (overhead power lines, water and tele lines) | 6 | 3.17 | 1.472 |
| Branching pattern and texture, bark, leaves | 6 | 1.50 | .837 |
| Mature size | 6 | 2.50 | 1.761 |
| Autumn coloring | 6 | 1.00 | .000 |
| Planting location | 6 | 3.17 | 1.602 |

As shown in (Table 4.13), respondents had varying levels of consideration for different factors when selecting street tree species. Respondents rated large canopy size as a medium consideration, with a mean value of 3.5. Aesthetics were considered very important, with all respondents rating them as a high consideration (mean value of 5). Stress resistance, ease of cultivation, and mass propagation were given low consideration, with a mean value of 1.83. Considering infrastructure (overhead power lines, water and tele lines) during planting the tree were rated at a medium level of consideration, with a mean value of 3.17. Branching pattern, texture, bark, and leaves were given very low consideration, with a mean value of 1.50. Mature size was considered a low consideration, with a mean value of 2.50. Autumn coloring was given very little consideration, with a mean value of 1. Planting the right trees in the right place was considered a medium-scale consideration, with a mean value of 3.17.

"When selecting the species, we avoided fruit tree because it creates conflict with animal and people and the other one is selecting torn free tree and evergreen plant for shade purpose."

*Table 4.14 Type of management service for urban street tree*

| How well are the following methods of street tree management being used? | | | |
|---|---|---|---|
| | N | Mean | Std. Deviation |
| Watering | 6 | 4.83 | .408 |
| Tickling | 6 | 4.67 | .516 |
| Pruning | 6 | 4.83 | .408 |
| Cutting | 6 | 4.67 | .516 |
| Compost | 6 | 3.33 | 1.366 |
| Security | 6 | 4.83 | .408 |
| Fertilizer | 6 | 3.33 | .983 |

The study found that respondents generally revealed the management practices for street trees after they were planted but most of this service focused on green area development not specifically street tree. These practices included watering, tickling, pruning, cutting, and security. All these practices were rated very highly, with mean values ranging from 4.67 to 4.83, indicating that there were very high levels of management practice. However, respondents rated the use of compost and fertilizer as a medium level of maintenance, with a mean value rate of 3.33 (

> "We implement a management practice for newly planted trees that includes watering them day and night, pruning and cutting within 3 months, and providing compost every 3 months."

> "Most of the time when selecting the species based on aesthetic value it is not good to select deep root, so that select the right species for the right space especially in media tree for example *Phoenix reclinata* (fiber root that does not cause infrastructure damage)."

"Most of the maintenance work was focused on grass work rather than street tree specifically. For grass management cut during the winter season, maintenance will be done every 2 months, while for summer; it will be done every month. Fertilizer will also be applied every 3 months and 0.5 kg of compost every month."


*Figure 4.13 Images of management practice (**A**–**C**). (**A**) pruning and cutting (b) tickling c) cleaning the littering leaf* *(Source: Author, 2023)*

**Suggested Solutions for Challenges of Developing and Management Street Tree by Respondents.**

The survey revealed that respondents provided various solutions to the challenges involved in street tree development and management. Some suggested creating public awareness and employing skilled workers to improve maintenance, while others recommended developing a well-planned management system to avoid conflicts with infrastructure and considering tree shade when planning the width of walkways and roads. Respondents also suggested selecting appropriate species based on expert advice, including deep-rooted and indigenous trees for shade and not just for beautification purposes. Additional solutions included installing fences for protection, focusing on street trees as opposed to just grass, and continuous pruning and cutting of tree branches. Respondents also emphasized the need for research-based solutions and mitigating problems related to a lack of planning. Lastly, they suggested working with other institutions involved in street tree development.

Experts have also appreciated the above solutions and suggested additional ones for future development. They emphasized the importance of considering factors such as growth habit, planting location, and species type when designing effective solutions. They also suggested involving stakeholders in the process of making policy decisions to ensure its effectiveness. Planting pits should be used to enhance growth, and public participation should be encouraged. Rules and regulations should be developed to penalize outsourced green organizations that fail to meet standards. Species selection should be based on thorough research, and better integration among different sectors is necessary. They finally emphasized the importance of working with skilled experts and checking utility and overhead lines before planting trees. Financing should also be modified to ensure successful implementation.

> Various techniques are provided to improve the growth of urban street trees, including the use of composts, ensuring adequate water supply, and safeguarding them against human and animal disturbances.

According to the respondents, they address to both federal and local standards that have an impact on the development and management of street trees. They also believe that involving other sectors can lead to better integration. Some of the representative responses from the respondents are as follows:

At the federal level, national policies, and strategic standards, such as the Ethiopia National Urban Green Infrastructure Standard, have been put in place to protect and ensure the proper implementation of street trees. These standards are then adapted and explained at the local city level, and there are also local rules that govern the use of green spaces. Anyone who causes harm to the street trees will be penalized, regardless of whether the damage is caused by humans, animals, or vehicles.

The existing rule is not being applied properly, as it should have been mandatory to follow the master plan and structural plan for all elements of the city.

"The involvement of multiple groups such as religious organizations, NGOs, government institutions like IDP and universities, public participants, and investors is necessary to enhance the growth and development of urban street .trees. "

### 4.1.4 Ecosystem Service Supply and Demand from Urban Street Tree

*Table 4.15Ecosystem service provision supply and demand from urban street trees overall*

| Ecosystem Service Category | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 378 | 2.99 | 4.34 |
| | Shade provision | 378 | 3.36 | 4.10 |
| Air quality regulation | Dust removal | 378 | 3.15 | 3.59 |
| | Smoke free air | 378 | 3.33 | 3.63 |
| | Noise reduction | 378 | 2.48 | 4.10 |
| Storm water management | Flood runoff control | 378 | 2.41 | 4.45 |
| | Trapping Rainwater | 378 | 2.45 | 4.20 |
| Aesthetic value | Inspiration | 378 | 3.32 | 3.81 |
| | Availability of seasonal beautiful foliage tree | 378 | 3.20 | 4.30 |
| | Longer pavement life | 378 | 3.24 | 3.73 |
| Recreation and human health | Physical exercise | 378 | 2.72 | 3.70 |
| | Emotional and psychological health | 378 | 3.20 | 3.92 |
| | Social setting | 378 | 2.99 | 4.31 |

| | | | | |
|---|---|---|---|---|
| | Space for recreation | 378 | 3.23 | 4.12 |
| Biodiversity | Tree species diversity | 378 | 2.79 | 4.08 |
| | Availability of birds and other wildlife | 378 | 2.83 | 3.50 |
| Food provision | Edible fruits | 378 | | 3.02 |
| Sense of place | Safe and familiar place | 378 | | 4.17 |

*Table 4.16 The five-point Likert scale is considered with range value.*

| Likert scale | scale | interval length | lower limit | upper limit | interval |
|---|---|---|---|---|---|
| Very poor/very low | 1 | 0.8 | 1 | 1.80 | (1:1.80) |
| Poor/low | 2 | 0.8 | 1.81 | 2.6 | (1.81:2.60) |
| Medium | 3 | 0.8 | 2.61 | 3.40 | (2.61:3.40) |
| Good /high | 4 | 0.8 | 3.41 | 4.20 | (3.41:4.20) |
| Very good/very high | 5 | 0.8 | 4.21 | 5 | (4.21:5) |

The survey of various segments of ecosystem service supplies like management, aesthetic value, recreation and human health, and biodiversity, including local climate regulation, air quality regulation, storm water was identified (Table 4.15).

For the first category of local climate regulation, which includes thermal comfort and shade provision, respondents indicated that shade provision for pedestrians along the street gives more service than thermal comfort, with mean values of 2.99 and 3.36, respectively. For the second category of Air quality regulation, which includes dust removal, smoke-free air, and noise reduction, the highest mean value was 3.33, indicating that most participants replied that the provision of smoke-free air was at a medium level, while the noise reduction service was at a poor level. The third category of Storm water management, which includes flood runoff control and trapping rainwater, had mean values of 2.41 and 2.45, respectively, indicating that most respondents replied that the provision of reducing raindrops and flow of runoff was in poor condition. For the fourth category of Aesthetic value, which includes inspiration, availability of seas beauty foliage trees, and longer pavement life, the mean values were 3.32, 3.20, and 3.24 respectively, indicating that most respondents replied that the provision of this ecosystem service from the street tree was in a medium scale. The fifth category of recreation and human health had different parameters, but most respondents believed that all parameters were available at a medium scale. The sixth category of biodiversity had two different parameters, with mean values of 2.79 and 2.83, respectively, indicating that the ecosystem provision was at a medium scale. These parameters were Tree species diversity and availability of birds and other wildlife.

In addition to assessing the supply of ecosystem service, the current and future demands of ecosystem service were also studied through eight different parameters, as shown in Table 4.15. For the first category of local climate regulation, which includes thermal comfort and shade provision, the mean value was 4.34, indicating that most respondents agreed that thermal comfort was demanded at a very high level, while the mean value of 4.10 showed that the majority of respondents agreed that shade provision by street tree during hot summers was demanded at a high level. For the second category of air quality regulation, which includes dust removal, smoke-free air, and noise reduction, the mean values were 3.59, 3.63, and 4.10 respectively, indicating that most participants demanded this service at a high level. The third category of stormwater management, which includes flood runoff control and trapping rainwater, had mean values of 4.45 and 4.20 respectively, indicating that respondents demanded these services at a very high and high level, respectively. For the fourth category of aesthetic value, which includes inspiration, availability of seas beauty foliage tree, and longer pavement life, the mean values were 3.81, 4.30, and 3.73, respectively, indicating that most respondents agreed that the demand for this ecosystem service was at a high, very high, and high level respectively. The fifth category of recreation and human health had different subcategories. For physical exercise, the mean value was 3.70, indicating that most respondents agreed that they needed it at a high level for sport activity. For emotional and psychological health, the mean value was 3.92, indicating that it was demanded at a high level. For social setting with people, the mean value was 4.31, indicating that it was demanded at a very high level. For space for recreation, the mean value was 4.12, indicating that it was demanded at a high level. The sixth category of biodiversity had two different parameters with mean values 4.08 and 3.50 respectively, indicating that this service was demanded at a high level. These parameters were Tree species diversity and availability of birds and other wildlife. The seventh category of food provision, which includes the cultivation of edible fruit for future demand, was rated with a mean value of 3.02, indicating that most participants demanded it at a medium level. The eighth category of Sense of place, which includes a Safe and familiar place, had a mean value of 4.17, indicating that most participants demanded it at a high level.

In addition to this overall ecosystem service provision the result shown above; this ecosystem provision differs based on the five-street segment as shown below because of different factors. Some of the factors are land use, street hierarchy and user dimension.

*Table 4.17 Ecosystem service supply and demand from Tesfaye Gizaw to Atote meberat*

| Ecosystem service categories | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 75 | 2.83 | 4.37 |
| | Shade provision | 75 | 3.40 | 4.11 |
| Air quality regulation | Dust removal | 75 | 3.27 | 3.51 |
| | Smoke free air | 75 | 3.55 | 3.37 |
| | Noise reduction | 75 | 2.84 | 3.77 |
| Stormwater management | Flood runoff control | 75 | 2.72 | 4.29 |
| | Trapping Rainwater | 75 | 2.39 | 4.03 |
| Aesthetic value | Inspiration | 75 | 3.40 | 3.56 |
| | Availability of seasonal beautiful foliage tree | 75 | 3.52 | 4.08 |
| | Longer pavement life | 75 | 3.39 | 3.69 |
| Recreation and human health | Physical exercise | 75 | 2.69 | 3.79 |
| | Emotional and psychological health | 75 | 3.31 | 4.03 |
| | Social setting | 75 | 2.79 | 4.53 |
| | Space for recreation | 75 | 3.21 | 4.23 |
| Biodiversity | Tree species diversity | 75 | 3.05 | 3.85 |
| | Availability of birds and other wildlife | 75 | 2.76 | 3.31 |
| Food provision | Edible fruits | 75 | | 2.92 |
| Sense of place | Safe and familiar place | 75 | | 3.97 |

The survey results (Table 4.17) showed most respondents believed that the first two parameters, local climate regulation and air quality regulation provision, were accessible or gained in a medium scale, with mean values ranging from 2.83 to 3.40, except for smoke-free air, which gained a good scale with a mean value of 3.55. The third parameter, stormwater regulation, was rated as medium for flood runoff control with a mean value of 2.72, and poor for trapping rainwater with a mean value of 2.39. The fourth parameter, aesthetic value, was rated as good for availability of seasonal beauty foliage tree with a mean value of 3.52, and medium for longer pavement life with a mean value of

3.39. The fifth and sixth categories, recreation and human health, and biodiversity provision, were both rated as accessible or gained in a medium scale, with mean values ranging from 2.69 to 3.31.

The survey also found that current and future demands for ecosystem services were categorized into eight parameters (Table 4.17). The first category, local climate regulation, including thermal comfort and shade provision, had a mean value of 4.37 and 4.11, indicating that most respondents demanded thermal comfort and shade provision at a very high and high level respectively. The second category, air quality regulation, including dust removal, smoke-free air, and noise reduction, had mean values of 3.51, 3.37, and 3.77, respectively, that indicates most participants have agreed these services were demanded at high, medium, and high levels, respectively.

The third category, Stormwater management, including flood runoff control and trapping rainwater, had mean values of 4.29 and 4.03, respectively, indicating that these services were demanded at very high and high levels. The fourth category, aesthetic value, including inspiration, availability of beauty foliage tree, and longer pavement life, had mean values ranging from 3.56 to 4.08, indicating that most respondents have agreed that the demand for these services are high.

The fifth category, recreation, and human health, including physical exercise, emotional and psychological health, social setting, and space for recreation, had mean values ranging from 3.79 to 4.53, indicating that most respondents agreed that the demand for these services was high to very high. The sixth category, biodiversity, including tree species diversity and availability of birds and other wildlife, had mean values of 3.85 and 3.31, respectively, indicating that ecosystem provision was in high and medium levels.

The seventh category, food provision, including cultivation of edible fruit for future demand, had a mean value of 2.92, indicating that most participants demanded it at a medium level. Finally, the eighth category, sense of place, including safe and familiar place, had a mean value of 3.97, indicating that most respondents demanded it at a high level.

*Table 4.18 Ecosystem service supply and demand from Tabor primary school to Hawassa agricultural college.*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 75 | 3.29 | 4.04 |
| | Shade provision | 75 | 3.67 | 3.79 |
| Air quality regulation | Dust removal | 75 | 2.81 | 4.03 |
| | Smoke free air | 75 | 3.27 | 3.89 |
| | Noise reduction | 75 | 1.99 | 4.35 |
| Storm water management | Flood runoff control | 75 | 1.36 | 4.81 |
| | Trapping Rainwater | 75 | 2.03 | 4.37 |
| Aesthetic value | Inspiration | 75 | 2.59 | 4.13 |
| | Availability of seasonal beautiful foliage tree | 75 | 2.64 | 4.39 |
| | Longer pavement life | 75 | 1.81 | 4.57 |
| Recreation and human health | Physical exercise | 75 | 1.67 | 3.67 |
| | Emotional and psychological health | 75 | 2.41 | 4.07 |
| | Social setting | 75 | 2.09 | 4.65 |
| | Space for recreation | 75 | 2.48 | 4.53 |
| Biodiversity | Tree species diversity | 75 | 2.29 | 4.05 |
| | Availability of birds and other wildlife | 75 | 2.83 | 3.79 |
| Food provision | Edible fruits | 75 | | 3.01 |
| Sense of place | Safe and familiar place | 75 | | 4.15 |

A survey was conducted to assess the provision of ecosystem services by street trees. The results showed in Table 4.18 that most respondents believed that the first two parameters, which are local climate regulation and air quality regulation provision, were provided at a medium level. However, shade provision was at a good level, and noise reduction was at a poor level.

Regarding the third parameter, reducing flood runoff control by street trees was rated very poorly with a mean value of 1.36, while trapping rainwater was poorly provided with a mean value of 2.03, according to the survey participants.

For the fourth parameter, aesthetic value, including inspiration, availability of seasonal beautiful foliage trees, and longer pavement life, most respondents agreed that ecosystem services were poorly provided, with mean values of 2.59, 2.64, and 1.81, respectively. Except for seasonal beautiful foliage trees, provided at medium level with a mean value of 2.64.

Regarding the fifth parameter, physical exercise was rated very poorly with a mean value of 1.67, while improving emotional and psychological health, social setting, and space for recreation were all rated as poorly provided, with mean values of 2.41, 2.09, and 2.48, respectively.

For the sixth parameter, tree species diversity and availability of birds and other wildlife were rated as poorly and moderately provided with mean values of 2.29 and 2.83, respectively.

The survey indicated that most participants demanded high levels of ecosystem services from street trees. For thermal comfort and shade provision, most respondents demanded high levels, with mean values of 4.35 and 4.81, respectively. Dust removal and smoke-free air were demanded at high levels, with mean values of 4.03 and 3.89, respectively, while noise reduction was demanded at a very high level with a mean value of 4.35. Flood runoff control and trapping rainwater were both demanded at very high levels, with mean values of 4.81 and 4.37, respectively. Inspiration was demanded at a high level with a mean value of 4.13, while availability of seas beauty foliage tree and longer pavement life were demanded at very high levels, with mean values of 4.39 and 4.57, respectively. Physical exercise and emotional and psychological health were demanded at high levels, with mean values of 3.67 and 4.07, respectively, while social setting and Space for recreation were demanded at very high levels, with mean values of 4.65 and 4.53, respectively. Tree species diversity and availability of birds and other wildlife were demanded at high levels, with mean values of 4.05 and 3.79, respectively. Edible fruit was demanded at a medium level with a mean value of 3.01, and safe and familiar place was demanded at a high level with a mean value of 4.15.

*Table 4.19 Ecosystem service supply and demand from Hawassa university main campus to Hawassa textile*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 76 | 2.62 | 4.68 |
| | Shade provision | 76 | 2.87 | 4.55 |
| Air quality regulation | Dust removal | 76 | 2.50 | 3.79 |
| | Smoke free air | 76 | 2.89 | 3.86 |
| | Noise reduction | 76 | 2.37 | 4.20 |
| | Flood runoff control | 76 | 2.68 | 4.29 |

| | | | | |
|---|---|---|---|---|
| Stormwater management | Trapping Rainwater | 76 | 2.37 | 4.30 |
| Aesthetic value | Inspiration | 76 | 2.95 | 4.04 |
| | Availability of seasonal beautiful foliage tree | 76 | 2.86 | 4.39 |
| | Longer pavement life | 76 | 3.37 | 3.62 |
| Recreation and human health | Physical exercise | 76 | 2.82 | 3.74 |
| | Emotional and psychological health | 76 | 2.99 | 4.14 |
| | Social setting | 76 | 2.99 | 4.38 |
| | Space for recreation | 76 | 3.26 | 4.24 |
| Biodiversity | Tree species diversity | 76 | 2.51 | 4.46 |
| | Availability of birds and other wildlife | 76 | 2.79 | 3.61 |
| Food provision | Edible fruits | 76 | | 3.39 |
| Sense of place | Safe and familiar place | 76 | | 4.72 |

According to the survey results in Table 4.19, there are eight different categories of ecosystem service supply and demand.

For local climate regulation, the mean values for thermal comfort and shade provision were 2.62 and 2.87, respectively, indicating a medium level of provision. However, most participants demanded these services at a very high level, with mean values of 4.68 and 4.55, respectively.

For air quality regulation, the mean values for removing dust from the air, reducing smoke, and noise reduction were 2.50, 2.89, and 2.37, respectively, indicating a poor to medium level of provision. Most participants demanded these services at a high level, with mean values of 3.79, 3.86, and 4.20, respectively.

For stormwater management, the mean values for flood runoff control and trapping rainwater were 2.68 and 2.37, respectively, indicating a medium to poor level of provision.

However, most participants demanded these services at a very high level, with mean values of 4.29 and 4.30, respectively.

For aesthetic value, the mean values for inspiration, providing seasonal interest and natural beauty through foliage tree, and longer pavement life were 2.95, 2.86, and 3.37, respectively, indicating a medium level of provision. However, most participants demanded inspiration and Availability of seasonal beautiful foliage tree at a high to very high level, with mean values of 4.04 and 4.39, respectively, while longer pavement life was demanded at a high level with a mean value of 3.62.

For recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.74, 4.14, 4.38, and 4.24, respectively, indicating a high to very high level of demanded but most participants provision of these services were at a medium level with mean value 2.82,2.99,2.99 and 3.26, respectively .

For biodiversity, the mean value of tree species diversity and availability of birds and other wildlife were 2.51 and 2.79, respectively, indicating this service was provided at a poor to medium level. However, the mean values for tree species diversity and availability of birds and other wildlife were 4.46 and 3.61, respectively, indicating a very high and high level of demand.

For Food provision, the mean value for edible fruit was 3.39, indicating a medium level of demand. Finally, For Sense of place, the mean value for safe and familiar place was 4.72, indicating a very high level of demand.

*Table 4.20 Ecosystem service supply and demand from south star hotel to wanza*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 74 | 2.91 | 4.77 |
| | Shade provision | 74 | 3.31 | 4.42 |
| Air quality regulation | Dust removal | 74 | 3.23 | 3.58 |
| | Smoke free air | 74 | 3.23 | 3.86 |
| | Noise reduction | 74 | 2.31 | 4.23 |
| Stormwater management | Flood runoff control | 74 | 2.39 | 4.64 |
| | Trapping Rainwater | 74 | 2.64 | 4.49 |
| Aesthetic value | Inspiration | 74 | 3.69 | 3.70 |
| | Availability of seasonal beautiful foliage tree | 74 | 3.34 | 4.55 |
| | Longer pavement life | 74 | 3.69 | 3.54 |
| Recreation and human health | Physical exercise | 74 | 3.05 | 3.88 |
| | Emotional and psychological health | 74 | 3.36 | 4.05 |
| | Social setting | 74 | 3.32 | 4.26 |
| | Space for recreation | 74 | 3.45 | 4.12 |
| Biodiversity | Tree species diversity | 74 | 3.14 | 4.11 |
| | Availability of birds and other wildlife | 74 | 2.65 | 3.80 |
| Food provision | Edible fruits | 74 | | 2.59 |
| Sense of place | Safe and familiar place | 74 | | 4.15 |

The survey results in Table 4.20 showed that the 78 participants had varying opinions on the provision and demand of ecosystem services provided by street trees.

For local climate regulation, the mean values for thermal comfort and shade provision were 2.91 and 3.31, respectively, indicating a medium level of provision. Most participants believed that there was not enough tree shade provision. However, the majority of participants demanded a very high level of thermal comfort and shade provision, with mean values of 4.77 and 4.42, respectively.

For air quality regulation, the mean values for removing dust from air, reducing smoke, and noise reduction were 3.23, 3.23, and 2.31, respectively, indicating a medium to poor level of provision. Most participants demanded these services at a high to very high level, with mean values of 3.58 and 3.86 for dust removal and smoke-free air, respectively, and a mean value of 4.23 for noise reduction.

For stormwater management, the mean values for flood runoff control and trapping rainwater were 2.39 and 2.64, respectively, indicating a poor to medium level of provision. However, most participants demanded these services at a very high level, with mean values of 4.64 and 4.49, respectively.

For aesthetic value, the mean values for inspiration, availability of seasonal beautiful foliage trees, and longer pavement life were 3.69, 3.34, and 3.69, respectively, indicating a good level of provision. However, the availability of seasonal beautiful foliage trees was provided at a medium level, with a mean value of 3.34. Most participants demanded inspiration, availability of seasonal beautiful foliage trees, and longer pavement life at a high to a very high level, with mean values of 3.70, 4.55, and 3.54, respectively.

For recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.05, 3.36, 3.32, and 3.45, respectively, indicating a medium to good level of provision. Most participants demanded these services at a high level, except for space for recreation were demanded at very high level with mean value 4.26

For biodiversity, the availability of different tree species diversity and habitat for birds and urban fauna, were provided at a medium level with mean values of 3.14 and 2.65, respectively. The mean values for tree species diversity and availability of birds and other wildlife were 4.11 and 3.80, respectively, indicating a high level of demand.

For food provision, the mean value for edible fruit was 2.59, indicating a low level of demand and finally, for Sense of place, the mean value for safe and familiar place was 4.15, indicating a high level of demand.

Overall, the survey indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, and stormwater management.

*Table 4.21 Ecosystem service supply from St. Gabriel church to Fikir Lake*

| Ecosystem service | | N | Mean | Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 78 | 3.32 | 3.86 |
| | Shade provision | 78 | 3.54 | 3.63 |
| Air quality regulation | Dust removal | 78 | 3.94 | 3.06 |
| | Smoke free air | 78 | 3.71 | 3.21 |
| | Noise reduction | 78 | 2.87 | 3.94 |
| Stormwater management | Flood runoff control | 78 | 2.88 | 4.22 |
| | Trapping Rainwater | 78 | 2.83 | 3.81 |
| Aesthetic value | Inspiration | 78 | 3.95 | 3.64 |
| | Availability of seasonal beautiful foliage tree | 78 | 3.63 | 4.12 |
| | Longer pavement life | 78 | 3.90 | 3.23 |
| Recreation and human health | Physical exercise | 78 | 3.37 | 3.45 |
| | Emotional and psychological health | 78 | 3.88 | 3.35 |
| | Social setting | 78 | 3.74 | 3.74 |
| | Space for recreation | 78 | 3.72 | 3.49 |
| Biodiversity | Tree species diversity | 78 | 2.96 | 3.92 |

| | | | | |
|---|---|---|---|---|
| | Availability of birds and other wildlife | 78 | 3.09 | 3.04 |
| Food provision | Edible fruits | 78 | | 3.18 |
| Sense of place | Safe and familiar place | 78 | | 3.85 |

The study analyzed the provision and demand of ecosystem services across eight parameters, namely local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place. The mean values of the responses of 78 participants for each parameter were recorded in (Table 4.21).

For local climate regulation, the mean values for thermal comfort and shade provision were 3.32 and 3.54, respectively, indicating a medium and good level of provision. Most participants demanded a high level of these services, with mean values of 3.86 and 3.63, respectively.

For air quality regulation, the mean values for removing dust from air and reducing smoke were 3.94 and 3.71, respectively, indicating a good level of provision. The mean value for noise reduction was 2.87, indicating a medium level of provision. Participants demanded these services at medium to high levels, with mean values of 3.06 and 3.21 for dust removal and smoke-free air, respectively, and a mean value of 3.94 for noise reduction.

For Storm water management, the mean values for flood runoff control and trapping rainwater were 4.22 and 3.81, respectively, indicating a very high and high level of demand. These services were categorized as medium level of provision at respected places on the street.

For aesthetic value, the mean values for inspiration, availability of seasonal beautiful foliage tree, and longer pavement life were 3.95, 3.63, and 3.90, respectively, indicating a good level of provision. Participants demanded inspiration and availability of seasonal beauty foliage tree at a high level, with mean values of 3.64 and 4.12, respectively, while longer pavement life was demanded at a medium level with a mean value of 3.23.

For recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.37, 3.88, 3.74, and 3.72, respectively, indicating a medium to good level of provision. Most participants demanded these services at a high level, except for emotional and psychological health, which had a mean value of 3.35 indicating a medium level of demand.

For Biodiversity, the mean values for tree species diversity and availability of birds and other wildlife were 3.92 and 3.04, respectively, indicating a high and medium level of demand. Edible fruit was demanded at a medium level with a mean value of 3.18, while a safe and familiar place was demanded at a high level with a mean value of 3.85. These services were categorized as medium level of provision at respected places on the street.

**Observation checklist from ecosystem service supply**

*Table 4.22 Observation checklist from ecosystem service supply*

| Ecosystem service | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| | Tree canopy size | 26 | 2.75 | .797 |

| | | | | |
|---|---|---|---|---|
| Local climate regulation | Tree crown shape media | 26 | 1.65 | .797 |
| | Shade provision | 26 | 3.81 | 1.021 |
| | Thermal comfort | 26 | 3.12 | 1.143 |
| Air quality regulation | Dust removal | 26 | 3.23 | 1.107 |
| | Smoke free air | 26 | 3.31 | .970 |
| | Noise reduction | 26 | 2.85 | 1.156 |
| Stormwater management | Shading of pavement cars and buildings | 26 | 2.96 | 1.148 |
| | Availability of drainage infrastructure | 26 | 2.77 | 1.336 |
| | Street permeability | 26 | 2.38 | 1.061 |
| | Level of water rain in the area | 26 | 3.92 | 1.093 |
| Aesthetic value | Availability of seasonal beautiful foliage tree | 26 | 2.42 | 1.027 |
| | Planting pattern | 26 | 2.85 | 1.084 |
| | Comfort for movement | 26 | 3.31 | 1.050 |
| | Visual aesthetics | 26 | 3.27 | 1.079 |
| Recreation and human health | Availability of amenities under a tree | 26 | 2.23 | 1.142 |
| | Space for recreation | 26 | 2.58 | .987 |
| Biodiversity | Availability of birds and other wildlife | 26 | 3.58 | 1.206 |

**Note**: - interval scale for tree canopy size and crown shape for media tree rate with 3 scale which is large (2.61:3.60), medium (1.81:2.60) and small (1:1.80) but the other value the same as the above interval scale.

From the above street scape element, different parameters were rated based on personal observation checklist including the six categories. The first one was local climate regulation include tree canopy size with mean value of 2.75 which means it is large canopy size in both walk way ,tree crown shape media the mean value  of 1.65 means crown shape for media tree small canopy coverage, shade provision mean value of 3.81 availability of shade along the street gained in good scale and thermal comfort mean value of 3.12 gained in medium scale, the second air quality regulation that include dust removal, smoke free air, noise reduction and Shading of pavement cars and buildings mean value range (2.85-3.31) which means this ecosystem service supply accessible or gained in medium scale. The third category is storm water management that include shading of pavement cars and buildings and availability of drainage infrastructure with mean value of 2.96 and 2.77 respectively this indicates availability of shade and conventional drainage at medium scale but for street permeability mean value of 2.38 which means permeable type pavement that help to reduce runoff in the surface available at poor scale. Level of water rain in the area with mean value of 3.92 which means there is high level run off in the surface. The fourth category is aesthetic values that include different parameters mean value range (2.85-3.27) which means availability of this service at medium scale except Availability of seas beauty foliage tree mean value 2.42 this service gained at poor scale. The fifth one is Recreation and human health includes two parameters mean value rate (2.23 and 2.58) which means this service gained in poor level. The six category is biodiversity availability of birds and other wildlife mean value 3.58 available in good scale as indicated at (Table 4.22).

## 4.2. Discussion

*Status, Species Composition*

From the survey, it was observed that most of the street trees across all the five studied streets were exotic species, with the percentage ranging from 66% to 82%. The percentage of indigenous tree species ranged from 21% to 33%. The most abundant species varied across streets, with *Grevillea robusta* being the most common species on two of the streets(street 2 and street 3) indicating that the urban environment in Hawassa is dominated by non-native species. The dominance of exotic species could be attributed to their ornamental value, fast growth rate, and adaptability to urban conditions. However, the use of exotic species in urban forestry has been a subject of debate, with some studies suggesting that the introduction of non-native species can have negative impacts on biodiversity, ecosystem services, and human health (Pauleit et al., 2019; Qureshi et al., 2015).

Studies have also shown that the use of indigenous species in urban forestry can provide a range of benefits, such as enhancing biodiversity, supporting local ecosystems, and providing cultural and ecological services (Gomez-Baggethun et al., 2013; Jim and Chen, 2008). Furthermore, indigenous species are better adapted to local climatic conditions, require less maintenance, and are more resilient to pests and diseases (Gomez-Baggethun et al., 2013; Jim and Chen, 2008). Therefore, incorporating indigenous species into urban street tree can help to improve the sustainability and resilience of urban ecosystems service.

In summary, the study highlights the need for a balanced approach to urban street tree, incorporating both exotic and indigenous species. While exotic species may have some benefits, the use of indigenous species can provide additional benefits, particularly in terms of biodiversity and ecosystem services.

*Status, Street scape*

The study assesses the status of streetscape elements, including street trees, street lighting, street furniture, bicycle racks, and pavement, in the studied street segments. The findings suggest that the availability of street furniture, bicycle racks, and pavement were generally perceived to be in poor to very poor condition across all streets. Street furniture, such as benches, signage, and trash cans, is essential for creating a convenient and comfortable environment for pedestrians (Seo and Kim, 2019). However, the availability of street furniture in the studied street segments is rare or limited to specific locations in addition, bicycle racks and other cycling infrastructure are also essential for promoting active transportation and reducing car dependency (Cervero and Duncan, 2003). However, the availability of bicycle racks in the studied street segments is under-conditioned, and most cycling users park their bicycles on the carriage way or other inappropriate locations. Furthermore, a study of the pavement quality is crucial for ensuring comfortable and safe movement for pedestrians and cyclists (Wang et al., 2017). However, the pavement types used in the studied street segments are causing issues such as unevenness, high runoff, and open ditches, making movement difficult in some places. On the other hand, sidewalk trees and median trees were generally perceived to be in good condition, except for Street

3 where median trees were perceived to be in poor condition. A study by Dover and Massengale (2013) showed that Street trees are the most important organizing element of the streetscape environment. Appropriate tree species selection and location and design of the planting site will ensure the healthy growth and longevity of trees, enhance streetscape character.

Street lighting system was generally perceived to be in good condition, while safety and security were perceived to be in medium condition. Furthermore, street lighting is crucial for creating a safe and secure environment for pedestrians, especially at night (Shi et al., 2019). However, the availability of street lighting in good condition but regardless of safety and secure is not sufficient to ensure safety, particularly after early midnight. Finally, the availability of flower stands varied across streets, with a general trend towards very poor or poor condition but few studies to date have revealed that street trees in combination with other smaller plants or flower stands are seen as more aesthetic than a single structure made up of trees. In studies regarding preferences for street-planting models in Japan (e.g. Fujiwara and Tashiro, 1984; Masuda et al., 1989; Abe et al., 1990), the results suggest that there is a need for more attention to be given to streetscape elements in the studied street segments. By providing street trees, street lighting, street furniture, bicycle racks, and high-quality pavement, communities can promote sustainable development and enhance the quality of life for street user. Furthermore, future research could focus on identifying the most effective strategies for improving streetscape elements and their impact on ecosystem service provision.

*Street tree development and challenge*

The survey results presented in this study highlight several challenges associated with street trees, including tree littering, failure of trees, and conflict with infrastructure. These challenges were rated as high to very high scale by most respondents, indicating the need for careful planning and management of street trees. Aesthetics were considered very important when selecting street tree species, while stress resistance, ease of cultivation, and mass propagation were given low consideration. Respondents generally approved of the management practices for street trees after they were planted, with high ratings for watering, pruning, cutting, and security. However, the use of compost and fertilizer was considered a medium level of maintenance. Most of the maintenance is more focused on the grass, not the tree specifically.

Studies have shown that there are significant gaps in the development and management of urban street trees. One of the main issues is that important tasks related to tree management are often outsourced to low-paid enterprises with limited knowledge of urban street tree management (Tiwari & Kumar, 2019). This can lead to inadequate care and maintenance of street trees, which can result in safety hazards and reduced ecosystem provision benefits. In addition to these challenges associated with street trees, including maintenance issues, conflict with infrastructure, and the need for careful species selection and management practices. For example, a study by Jim and Chen (2018) found that urban tree management faces challenges such as limited budgets, lack of skilled personnel, and conflicts with infrastructure. Similarly, a study by Escobedo et al., (2011) identified the importance of careful species selection and management practices to ensure the success of urban tree-planting programs. Additionally, a lack of clear policies and guidelines can lead to inconsistent management practices and ineffective decision-making (Jim and Chen, 2018).

Another issue is the lack of support from municipal departments for native tree planting in the city. Most of the existing trees are exotic species chosen for their aesthetic value, rather than their ecological benefits (López et al., 2018). However, planting more native trees could be an opportunity to bring people closer to nature and support urban biodiversity, as native trees are better adapted to local conditions and provide important habitat for wildlife.

To address these gaps, it is necessary to implement measures such as regular pruning and maintenance, careful species selection, and strategic placement of trees to avoid blocking views or traffic signs. These measures can help to mitigate the challenges associated with street trees and enhance their benefits. Additionally, involving local communities and professionals in the decision-making process is crucial to ensure that street trees are managed in a way that aligns with their needs and preferences (Jim and Chen, 2018). Finally, adequate funding and resources must be allocated to support the development and management of street trees (Tiwari and Kumar, 2019). By taking a balanced approach that considers both the benefits and challenges associated with street trees, it is possible to effectively manage and enhance the urban street tree to give the expected ecosystem provision.

Overall, these findings suggest that effective management of street trees requires careful planning and consideration of a range of factors, including species selection, maintenance practices, and infrastructure considerations. By addressing these challenges, urban areas can enjoy the many benefits of street trees, including improved air quality, reduced urban heat island effects, and enhanced aesthetic values and other ecosystem service.

### *Ecosystem supply and demand*

This study, the survey results identified six segments of ecosystem service supply: Local climate regulation, air quality regulation, stormwater management, aesthetic value, recreation and human health, and biodiversity. For Local climate regulation, shade provision was perceived to provide more service than thermal comfort. In other study street trees have been found to provide multiple benefits, including reducing air pollution, mitigating urban heat island effects, and enhancing the aesthetic quality of the street environment (Zhang et al., 2019). Street trees also provide shade, which can reduce the temperature of the pavement surface and make walking more comfortable for pedestrians. However, the availability of street trees in the studied street segments is under medium condition, with unplanned trees and a lack of spacing planning between trees in addition to this thermal comfort plays an important role in determining the quality of life in cities. The thermal comfort of urban pedestrians influences their choice and level of outdoor activities and the utilization of urban space (Huang et al.,2015). In other study urban thermal environment is influenced by ground cover, including vegetation cover and impervious surfaces, as well as the geometry of street canyons (Johansson, 2006), In terms of air quality regulation, smoke-free air provision was in medium condition, while noise reduction service was rated as poor. The study found that the provision of noise reduction by street trees was perceived to be at a poor level by respondents, while the Barcelona study found that street trees provide noise reduction benefits. Another study by (Kabisch et al.,2022)) found that urban residents expect trees to provide a range of benefits, including improving air quality and reducing noise levels, furthermore a study by (Tallis et al., 2011) street trees can be particularly effective at capturing airborne pollutants in urban areas. For stormwater management, reducing raindrops and flow of runoff provision was perceived to be in poor condition. Some studies have indicated that tree plantings, green filter strips, rain gardens, and bioretention swales are effective measures for controlling urban stormwater by reducing the volume and peaks of runoff (Marsalek et al., 1993). Regarding aesthetic value, ecosystem service provision from street trees perceived under medium condition. However, (Miller and Johnson .,2017) investigated the impact of foliage color on aesthetic value and discovered that trees with vibrant and contrasting foliage colors were perceived as more visually appealing Furthermore, (Smith et al. ,2018) conducted a survey among urban residents and found that the presence of street trees significantly enhanced the overall aesthetic appeal of streetscapes. In terms of recreation and human health, most parameters were rated as available at a medium scale, except for physical exercise, which was rated as poor, while other studies have found that access to green spaces and street trees can promote physical activity (Kaczynski et al., 2014).However , Another study by Kabisch et al., (2022) found that urban trees can provide important benefits for human health and well-being, but these benefits are often not realized due to inadequate management practices and planning.

For biodiversity, the provision of tree species diversity and availability of birds and other wildlife under medium conditions, while a study by (Shashua-Bar et al.,2015) found that urban residents value the biodiversity and ecosystem services provided by trees in urban areas. Similarly, a study by( Yang et al., 2020) found that increasing tree species diversity in urban areas can provide important benefits for urban biodiversity and ecosystem services.

The survey also assessed the current and future demands of ecosystem service by including eight different parameters. For Local climate regulation, thermal comfort was in high demand, while shade provision during hot summers was in high demand. A study by Jim and Chen (2018) found that the demand for urban trees to provide shade and cool urban environments is high in hot and dry regions, but the provision of these services is often inadequate due to poor tree management practices and lack of investment in tree planting and care. For instance, a study by (Pauleit et al.,2019) found that urban trees are important for regulating urban microclimates, but their effectiveness varies depending on the species, location, and management practices. For Air quality regulation, dust removal, smoke-free air, and noise reduction services were in high demand. Some Studies have indicated that vegetation, including trees, can significantly reduce dust levels in urban environments, improving air quality and reducing potential health risks (e.g., Grote et al., 2016; Yang et al., 2020). For Stormwater management, flood runoff control and trapping rainwater were in very high and high demand, respectively also in Some study suggests that effective stormwater management is crucial in urban areas to mitigate the negative impacts of intense rainfall events. Various stormwater management techniques, such as green infrastructure (e.g., rain gardens, bioswales) and permeable pavements, have been shown to effectively manage stormwater by promoting infiltration, reducing runoff, and improving water quality (Wright and Ogden, 2016; Li et al., 2019).For Aesthetic value, inspiration, availability of seas beauty foliage tree, and longer pavement life were in high, very high, and high demand, respectively. A Study by (Hartig et al., 2014) found that the presence of trees and green spaces enhances the aesthetic appeal of urban environments. Trees provide visual beauty, adding color, texture, and natural elements to the landscape. Studies have shown that people perceive tree-lined streets and green spaces as more aesthetically pleasing, contributing to a positive perception of the overall environment. For Recreation and human health, physical exercise, emotional and psychological health, social setting with people, and space for recreation were in high, high, very high, and high demand, respectively, while other studies have found Access to green spaces, including areas with street trees has a profound impact on recreation and human health. In terms of physical exercise, street trees provide shaded areas that invite people to engage in outdoor activities such as walking, jogging, and other forms of exercise. Studies have shown that the presence of street trees encourages physical activity and promotes an active lifestyle (Kaczynski et al., 2008; Sugiyama et al., 2008). Moreover, spending time in green environments, including streets lined with trees, has been scientifically linked to improved emotional and psychological health. These natural settings have a calming and restorative effect, reducing stress levels, enhancing mood, and benefiting overall mental well-being (Tyrväinen et al., 2014; Roe et al., 2013). Street trees also create attractive and welcoming social settings, fostering community engagement and social interactions. By providing pleasant spaces for people to gather, walk, and participate in recreational activities, street trees contribute to the development of social connections and a sense of belonging (Kuo et al., 2001; Ward Thompson et al., 2016). Furthermore, street trees play a vital role in providing spaces for recreation. They offer shaded areas that are ideal for relaxation, picnicking, and other leisure activities. This enhances the quality and appeal of urban environments, providing residents with accessible and enjoyable opportunities for recreation (Wolf, 2005; Fan et al., 2020). Biodiversity in urban areas, including tree species diversity and the presence of birds and other wildlife, is highly demanded. Research suggests that having a wide variety of tree species in urban environments can offer numerous benefits to biodiversity. This diversity provides habitats and food sources for various wildlife species, contributing to the enhancement of urban biodiversity and ecological resilience (Dearborn and Kark, 2010; Lerman et al., 2012) The demand for food provision through street trees, including the cultivation of edible fruit, is moderate. However, there are differing viewpoints regarding the suitability of street trees for food provision. One perspective argues against street tree food provision, citing concerns about cleanliness and hygiene. Research indicates that street trees can accumulate pollutants, such as heavy metals, from urban environments. This accumulation may pose a risk of contamination to the edible fruits they produce (Nowak et al., 2013; Dobbs et al., 2017). This viewpoint emphasizes the potential health risks associated with consuming fruits from street trees, raising concerns about the safety of such food sources. On the other hand, an opposing perspective argues in favor of street tree food provision, highlighting its potential benefits. Street trees can contribute to food security, particularly in urban areas with limited access to fresh produce. They provide a locally grown source of nutritious food and can promote community engagement and urban agriculture initiatives (Orsini et al., 2014; McClintock et al., 2016). Research supporting street tree food provision emphasizes the potential for increasing urban food production and enhancing community resilience. The demand for a safe and familiar place as part of the sense of place is consistently high. Several studies have explored the cultural and historical significance of street trees in specific contexts. They have found that street trees can symbolize heritage, traditions, and local identity, there by influencing the sense of place for residents and visitors (Beery and Jönsson, 2017; Kothencz et al., 2017). Furthermore, street trees contribute to a sense of identity and distinctiveness, making streets more recognizable and memorable. When well-maintained and diverse, street trees evoke positive emotions, enhance people's overall perception of the street, and encourage them to spend more time in the area.

Overall, the survey indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, storm water management, and sense of place indicates that there is a significant gap between the provision of and demand for ecosystem services provided by street trees in urban areas. a study conducted in the city of Melbourne found that street trees provide several ecosystem services, including local climate regulation, air quality regulation, storm water management, and biodiversity (Escobedo et al., 2011). Another study conducted in the city of Barcelona found that street trees provide multiple benefits, including local climate regulation, air quality regulation, noise reduction, and aesthetic value (Beery and Jönsson, 2017).

# Chapter five: Conclusion and Recommendation

## 5.1 Conclusion

Urban street trees play a crucial role in providing essential ecosystem services that enhance the health and well-being of urban street user. However, in the city of Hawassa, there is a significant gap between the supply and demand of these ecosystem services. This study was conducted on five different street in Hawassa City and ecosystem services examined in this study are local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place.

This survey indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, storm water management, and sense of place. This Indicates that there is a significant gap between the provision of supply and demand for ecosystem services provided by street trees in Hawassa city. This imbalance is attributed to challenges in street tree development and management, as well as a lack of attention to other streetscape elements that can enhance the benefits of street trees.

Finally, the study forwards a recommendation for enhancing the current status of street tree and for future development and forwards new possible design prototypes that considers the demand of ecosystem provision to minimize the gap between supply and demand. In general, further study needs on identifying the most effective ways to provide these ecosystem services and how to balance the supply and demand of these services in urban areas

## 5.2 Recommendation

Based on the study's findings, general recommendations were developed to improve the ecosystem service provision balance, management and development of urban street trees and streetscapes. To address the challenges and issues identified, the following recommendations are suggested.

**criteria for selection of species**

- When planting a Street tree must consider with site constraints such as verge widths, overhead power lines, building setbacks and the final mature size relevant with street width.
- when selecting a species must be chosen for its predictable growth pattern and form.
- When selecting a street tree should have a single or straight trunk.
- When selecting a tree's canopy should have broad, domed branches and evergreen foliage.

**For Academicians**

- There is a need for more comprehensive studies on the specific mechanisms through which street trees influence urban microclimates and ecosystem service they give.
- More research on urban ES by using more comprehensive stakeholder involvement.
- Integrated research efforts, and translation of scientific findings into actionable knowledge, feeding information back into planning and management.

**For Street user or community**

- The community must take steps to protect animals that may be left without care and are causing damage to urban street trees.
- street user must utilize street tree in a responsible manner, ensuring that they are not damaged or negatively impacted.
- To address the provision of street tree services for all levels and types of users, streets should be designed to accommodate a variety of users, not just cars. This can be achieved by creating dedicated lanes for pedestrians, cyclists, and public transit, among others.
- When developing street tree initiatives, it is crucial to consider the community's demands and preferences regarding street trees identify potential tree species for selection according to desired services.

**For Hawassa municipality and Policymakers**

- The municipality should engage in proper planning and implementation of adequate compensation measures for individuals who may be displaced due to urban street tree development.
- When planting a street tree, it is important to consider a range of ecosystem services (ES) it can provide, rather than only focusing on its aesthetic value. Planting decisions should prioritize the multiple benefits that street trees can offer to the urban environment.
- To improve the management and development of urban street trees and streetscapes, the concerned government officials should prioritize strong integration and coordination among different stakeholders.
- The City Beautification Municipality strengthened its legal framework to protect urban street tree areas from damaging activities by the community and outsource organizations, rather than relying on weak administrative control.
- A specialized organization should exist with the responsibility of defining guidelines, approaches, and values related to achieving appropriate development and management.
- The responsible body should integrate various stakeholders such as local communities and various experts throughout the design process.
- There should be continuous maintenance and care for street tree for a better environment. This could include selecting and replacing old tree with mindful and professional care.
- It is necessary to create guidelines for the development and management of urban street trees.

- When designing streets, landscape proposals must be created by considering the street tree's ecosystem services and its relationship to other streetscape elements.
- When designing urban street tree, it is important to conduct a thorough analysis and research to consider the design of other street scape elements.
- Understanding the supply and demand of ecosystem services provided by street trees. It helps inform decisions regarding tree species selection, planting locations, and maintenance practices to maximize the benefits of street trees for both the community and the environment.
- To effectively implement and achieve the necessary measures, it is essential to allocate a sufficient budget.

In general, the municipality's sanitation, beautification, and green area development and management processes should prioritize collaboration with other stakeholders, including forest and environmental conservation institutions, agriculture and nature offices, NGOs, private sectors, communities, and other governmental offices. A multidisciplinary approach to stakeholder involvement is critical for successful urban street ecosystem provision.

### 5.2.1 Specific Site Recommendations

The design proposal integrates the above recommendations with findings and discussions of the research. The design might not be the only approach to make a street tree given the demanded ecosystem service; instead, it could be used as a prototype to the other street for the new and other for future development. From the five streets that studied the researcher selected street segment from **Hawassa university main campus to Hawassa textile to** propose appropriate and contextualized landscape design**.**

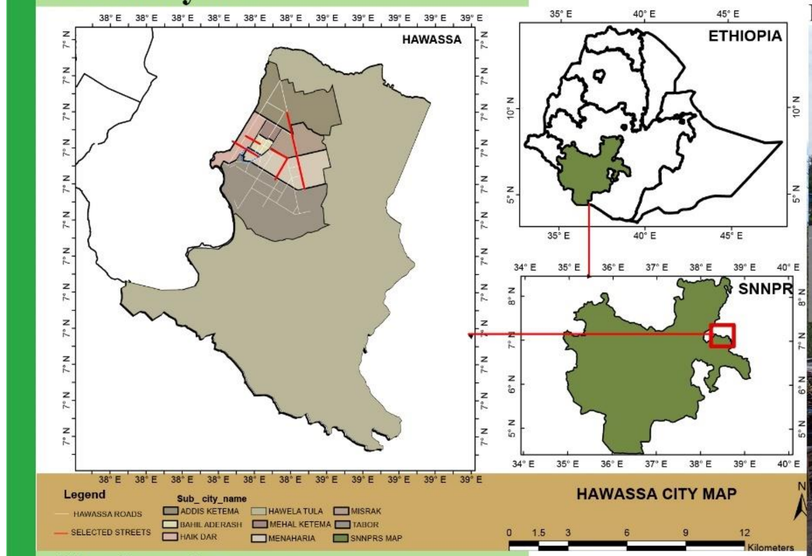
This site selected because of different reason the first one is the data collected from the five different street segment which is from this street segment the result show most of the major problem from very poor to medium rate by users in this segment as indicated in (Table 4.19) rather than from other street so if we design this site it will apply for other street place as a prototype .

In addition to this the street a figure of Hawassa because it is major road that connect different city because of street hierarchy PAS, in addition more street user are available because of the land use that include industrial park and university that active the site during the day and night time that will help more user engage to the site

Furthermore, the site has a potential to not only walkway or movement space it can street park .it can contain different activity that improve vibrant the space, ecosystem provision value and economic value.

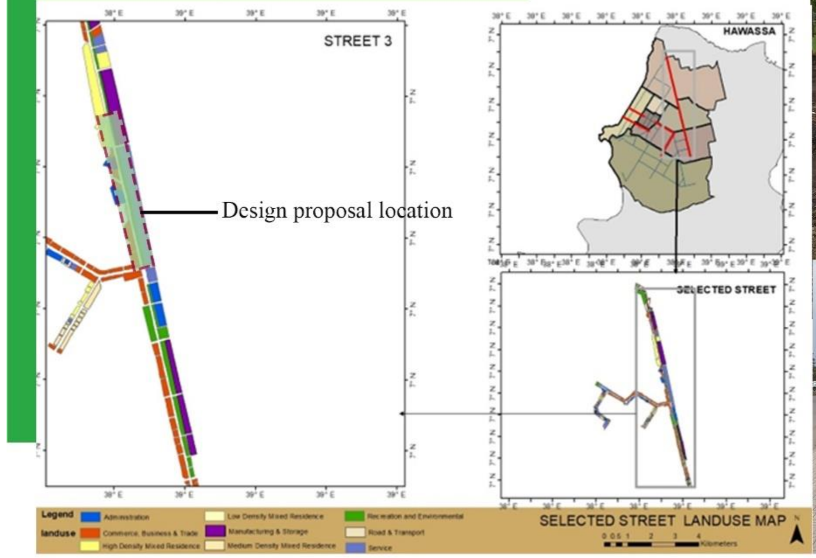
In the proposed design, the design prioritizes the most critical ecosystem demands of urban street trees, including **storm water management, providing thermal comfort, seasonal beauty foliage, creating a sense of place,** and **facilitating social interaction** incorporated with streetscape elements such as street lighting, signage, street furniture, parking lots, bikeway and bicycle racks, and trash cans will be placed in the respected place.

## Site Anlaysis




Existing condition of the site


## Site Location




The problem of the existing site one of them is the placement of trees along the pedestrian walkway is inadequate, as they are too far away from walkway to provide the expected ecosystem services such as climate regulation and stormwater management. In some areas, there are no trees at all as indicated indicating a lack of proper planning based on standard street tree and median tree design. The majority of street trees are of the Grevillea robusta species as indicated in Appendix D , which does not adequately address the diverse ecosystem values needed for proper provision.

Furthermore, the existing problems with the carriageway are numerous and require meaningful solutions. The design of the median and pedestrian walk way, with its curbed and elevated structure, prevents storm runoff from the asphalt from reaching the median. Additionally, there is a lack of stormwater management practices such as infiltration trenches, rain gardens, and bioswales, rather than the existing conventional dich which does not allow infiltration and leads the whole runoff to nearby water shade has contributes for flooding.

The aim of the proposed design is to maximize the benefit of the walkway trees and median trees by incorporating highly demanded ecosystem provisions and streetscape elements.

## Case Study


Sector:Parks and Open Spaces
Services:Landscape Architecture, Master Planning, Urban Design
Client:Hudson Square BID/NYC DPR/NYC DOT
Location:New York, NY
Status:Complete
Completion:2018
Site area:25,152 SF

The plan proposes far-reaching initiatives to create a socially, economically, and environmentally sustainable network of spaces.Hudson Square Park is a paradigm of how private investment and public benefit can dovetail to better the city's public spaces.

The redesign of Spring Street Park was one of the first to be undertaken as part of the Hudson Square Streetscape Master Plan. This half-acre triangular open space is reimagined to accommodate a variety of activities for workers and residents alike. As the only public park within the neighborhood, it offers comfortable lunchtime seating and hosts performances and seasonal markets in the evenings and on weekends. For all visitors, the plaza has been transformed into a public place of major significance with a strong underpinning of environmental performance through stormwater capture, tree health, biomass production, dark-sky protection, and traffic calming.


## Case Study

### 2.Barton CSO Control with Roadside Rain Gardens Retrofit, Seattle

Project Area: 15 city blocks
Contributing Drainage Area: 32 acres
Right-of-Way Width: 60 feet
Participating Agencies: King County Wastewater Treatment Division
Timeline: Planning started 2009
Construction, 2013-2015

#### *Goals*

Stormwater management: Reduce combined sewer overflow events by at least 75%.
Demonstrate possibilities: Serve as a model for future green infrastructure retrofit projects for addressing combined sewer overflows.

#### *Overview*

The Barton CSO Control project is designed to address combined sewer overflows in the Barton Combined Sewer Basin from discharging into Puget Sound at an outfall near Lincoln Park in Seattle, a popular recreation area.

#### *Design Details*

King County constructed 91 bioretention cells with graded side slopes in the planter strip on 15 blocks in the project area. When it rains, stormwater filters through the bioretention facility soil to a slotted drain pipe, which takes the water to a deep well for slow infiltration underground. The project team determined the number of needed bioretention facilities through hydrologic/hydraulic modeling.

The design team sited bioretention facilities on residential, non-arterial streets that were relatively flat (under 5% grade) with few driveways. Sites were also selected to avoid public and private utility conflicts, have planting strips at least 2.7m wide, and have minimal impact to on-street parking and existing mature trees.

#### *Outcomes*

Preliminary monitoring and observations indicate that the rain gardens with the deep infiltration wells are performing as intended, and are infiltrating all the water that is draining into the facilities.

### 3.SE Division Street, Portland

Project Length: 1.6 mil
Right-of-Way Width: 60 feet
Participating Agencies: Portland Bureau of Environmental Services, Portland Bureau of Transportation
Timeline: 2009 – 2015

#### *Goals*

Stormwater management: Eliminate sewer backflows into basements and streets in the project area.
Water quality: Reduce the severity and frequency of combined sewer overflow events, meeting EPA guidelines for discharges to the Willamette River.
Mobility: Improve safety and comfort for people walking and biking along the corridor. Increase reliability and running speed of the heavily-used bus lines along the street.
**Access:** Increase access to local businesses by providing adequate on-street parking for cars and bikes.
**Placemaking:** Improve aesthetics of the corridor, with landscaped stormwater facilities, shade trees, and public art.

#### Design Details

The project eliminated peak-hour travel lanes along most of the corridor after finding that they were underutilized. By eliminating lanes, designers reclaimed space for other uses.
A curb-to-curb reconstruction of the corridor brought sidewalks up to standard width and added or redesigned corner ramps to make the street ADA compliant.
Large canopy trees were planted on the north side of Division Street throughout the corridor, avoiding utility conflicts on the south side. The trees help shade the street, intercept stormwater, and add attractive landscaping and traffic calming elements to the corridor.
Curb extensions with integrated stormwater facilities (often also extending into furnishing zones) manage excess stormwater runoff from the street, and also improve pedestrian safety by reducing crossing distance and enhancing visibility of pedestrians.
In some parts of the corridor, designers integrated stormwater facilities into furnishing zones to minimize impervious area while avoiding utility conflicts.
The project added on-street bike parking (bike corrals) throughout the corridor. By eliminating peak-hour travel lanes, the project also added additional on-street car parking along most of the corridor. In addition to enhancing the vitality of the retail landscape, bike and car parking add a buffer between moving traffic and pedestrians on the sidewalk.

#### *Overview*

SE Division Street was a deficient transportation corridor with varying land use and many competing needs.
The street was redesigned to include fewer but better-performing travel lanes, along with curb extensions, marked crossings, improved bus stops, on-street bike parking, bioretention planters to manage stormwater runoff, and large canopy trees along the corridor to provide shade and improve water quality.

## Project program and Concept development

### Project program

**Ecosystem service**

The project program was determined by prioritizing specific ecosystem services identified during the data analysis, while also considering the integration of other streetscape elements.

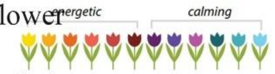
**-controlling flood/runoff,** by using bioswales, curb extension ,infiltration ditch , rain garden and pervious pavement

bioswale

curb extension

**-providing thermal comfort,** providing wide crown shape tree

**-seasonal beauty foliage,** by adding colorful tree and flower




**-creating a sense of place,**

**-social setting** by facilitating social interaction like providing street café, picnic space, reading space and providing street job place

**streetscape element:** street lighting, signage, street furniture, parking lots, bikeway and bicycle racks, and trash cans

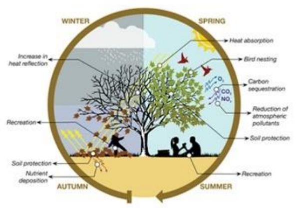
Sitting Bench with green

### Concept development

### Eco network street

**Social Benefit**

**Ecosystem service Benefit**

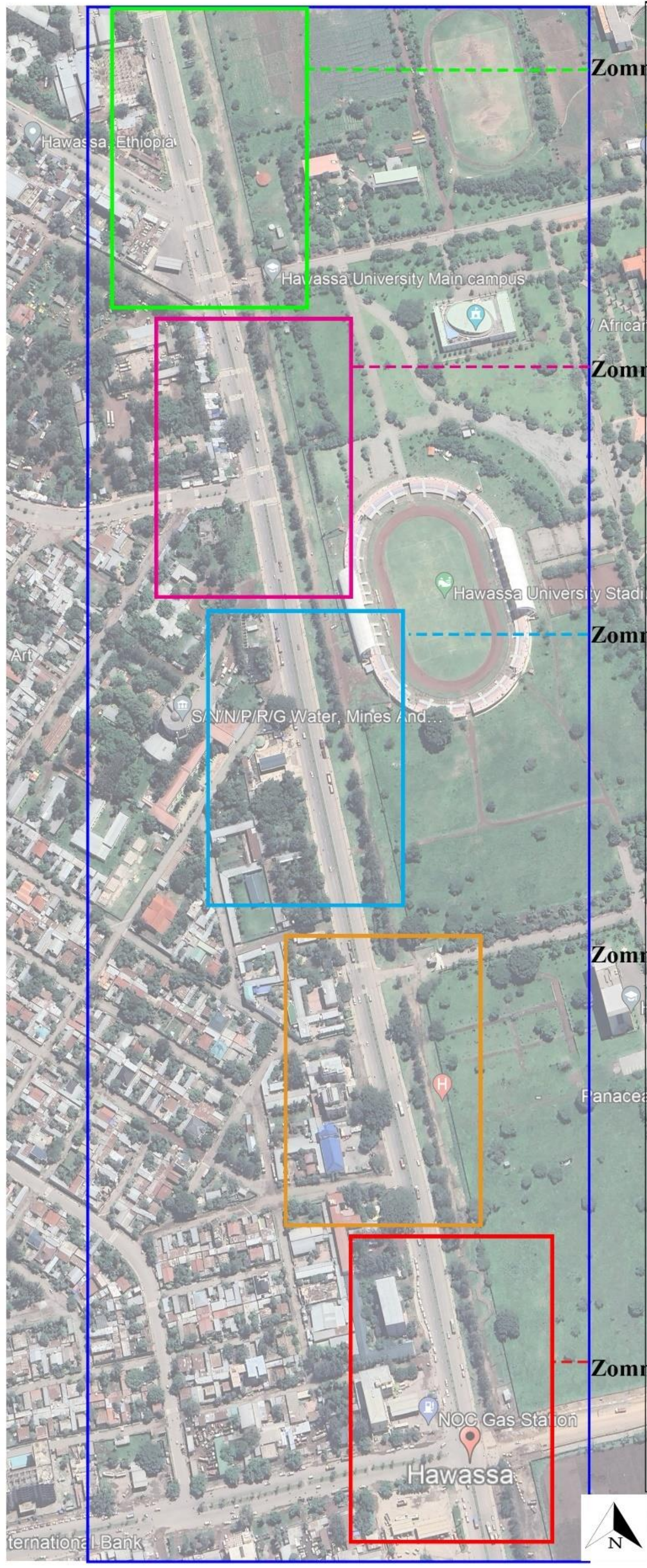



**Economical Benefit**

Street job

The streets act as connectors that link people socially, ecologically, and economically, providing various benefits and creating a vibrant space. Street trees, along with other streetscape elements, play a crucial role in facilitating these connections. By incorporating street trees into the urban landscape, people are provided with not only aesthetic appeal but also social gathering spaces that foster interaction and community engagement. Additionally, these trees offer ecosystem services, such as improved air quality, controlling flood/runoff, providing thermal comfort, seasonal beauty foliage, and creating a sense of place.

**Hawassa main university to Hawassa textile**

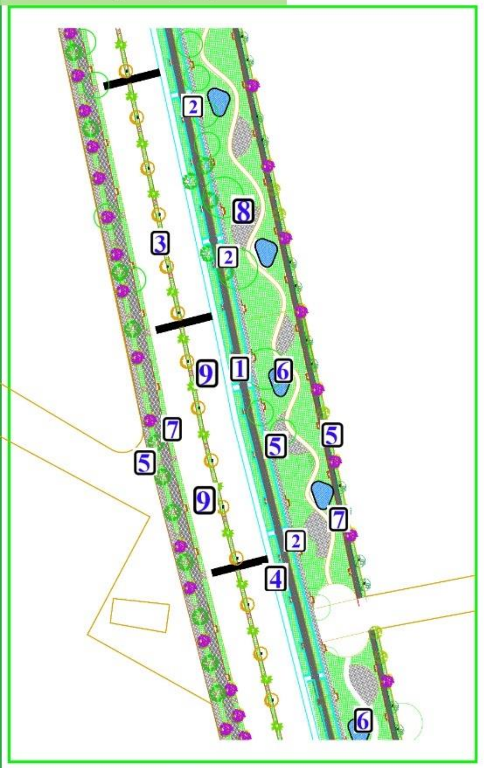



## Site plan

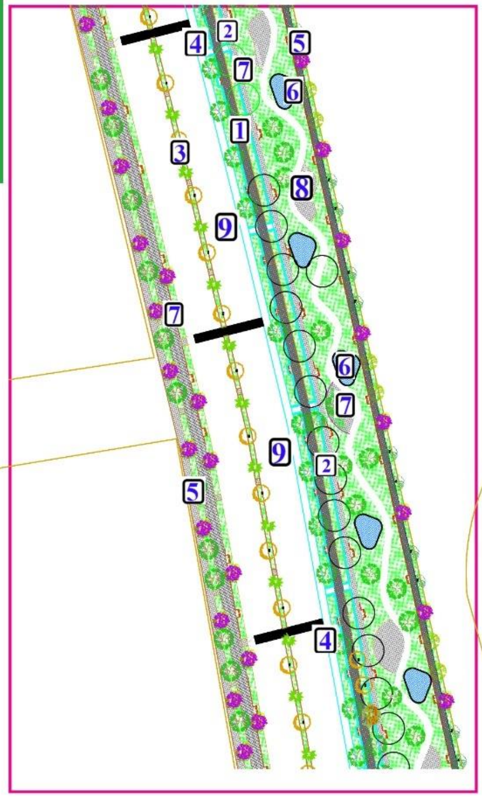
## Hawassa main university to Hawassa textile

## Z1 & Z2 plan

Zommed plan [Z1]



Zommed plan [Z2]

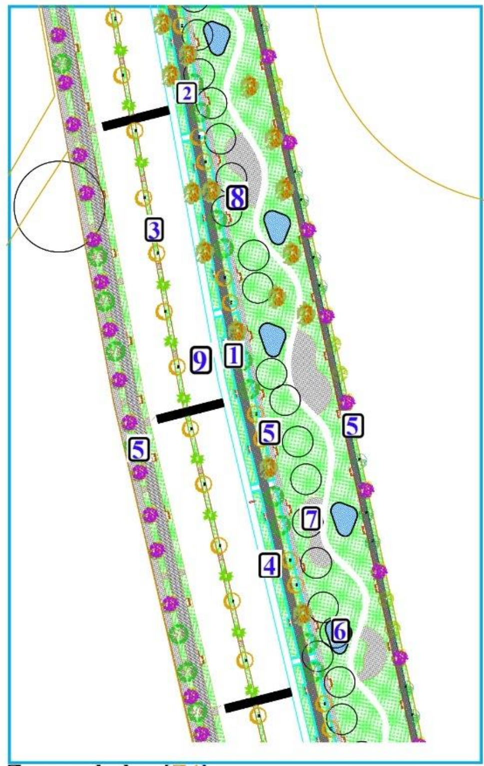


### Legend

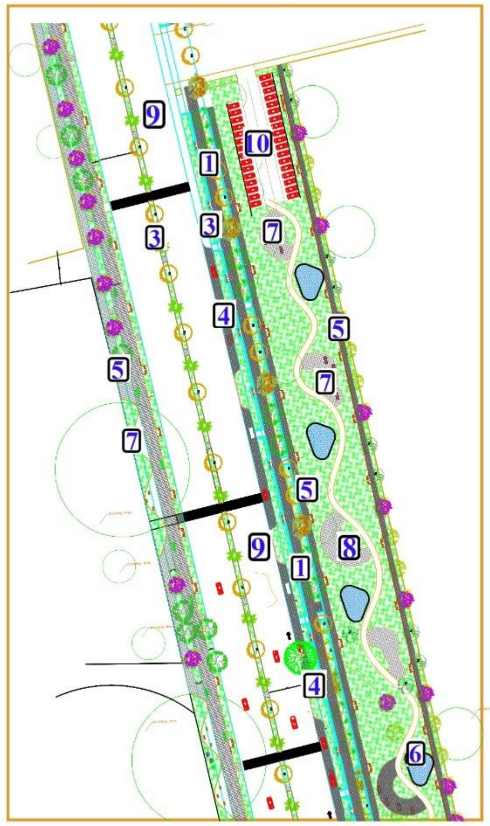
1.Bicycle lane
2.Bicycle rack/parking
3.Bioswale
4.Curb extension
5.Pedestrian lane
6.Rain garden
7.Sitting
8.Street business
9.Vehicle lane
Existing Tree

## Z3&Z4

Zommed plan [Z3]



Zommed plan [Z4]



### Legend

1.Bicycle lane
2.Bicycle rack/parking
3.Bioswale
4.Curb extension
5.Pedestrian lane
6.Rain garden
7.Sitting
8.Street business
9.Vehicle lane
10.Vehicle parking

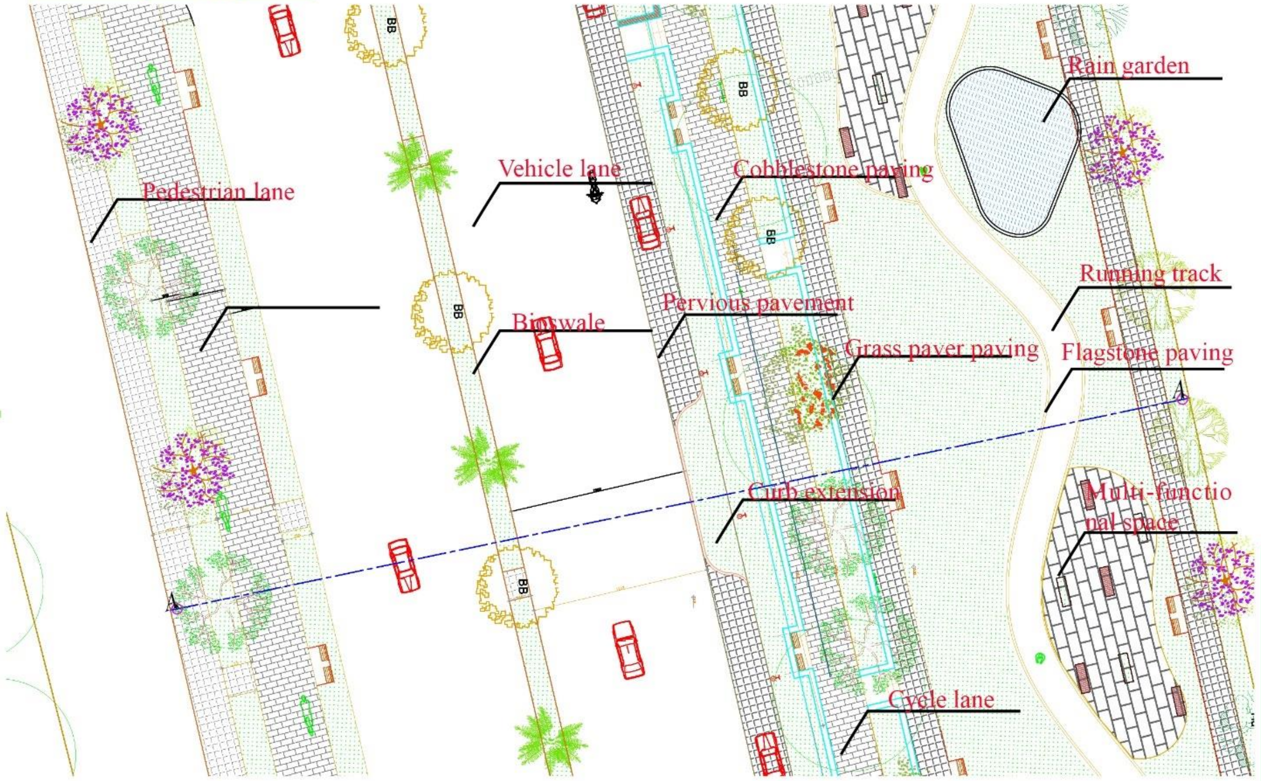
Existing Tree

## Hawassa main university to Hawassa textile

Zommed plan [Z5]


## Z6

Zommed plan [Z6]

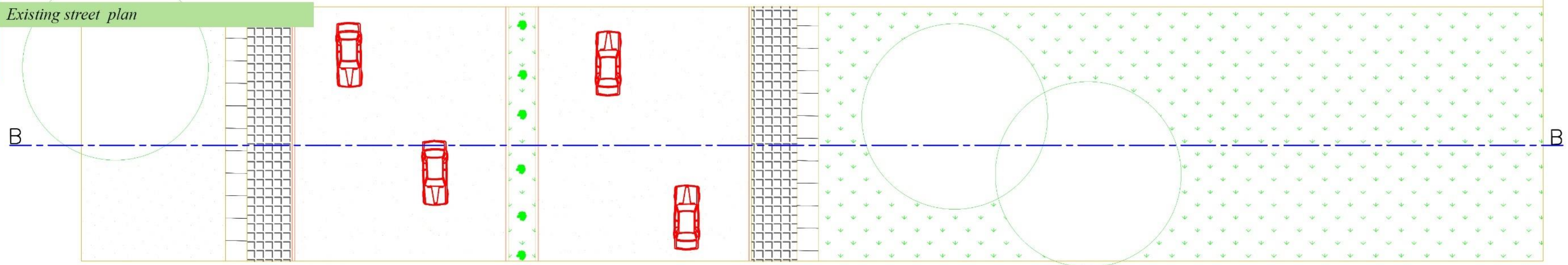


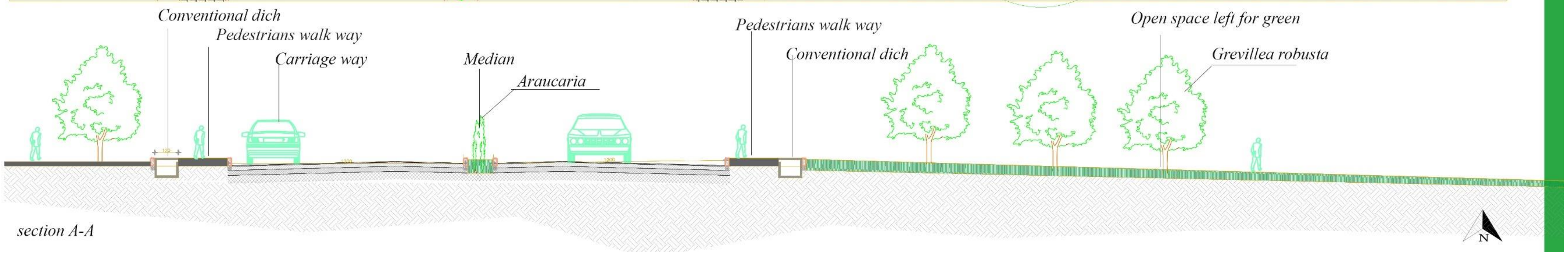

**Legend**

1. Bicycle lane
2. Bicycle rack/parking
3. Bioswale
4. Curb extension
5. Pedestrian lane
6. Rain garden
7. Sitting
8. Street business
9. Vehicle lane
10. Vehicle parking

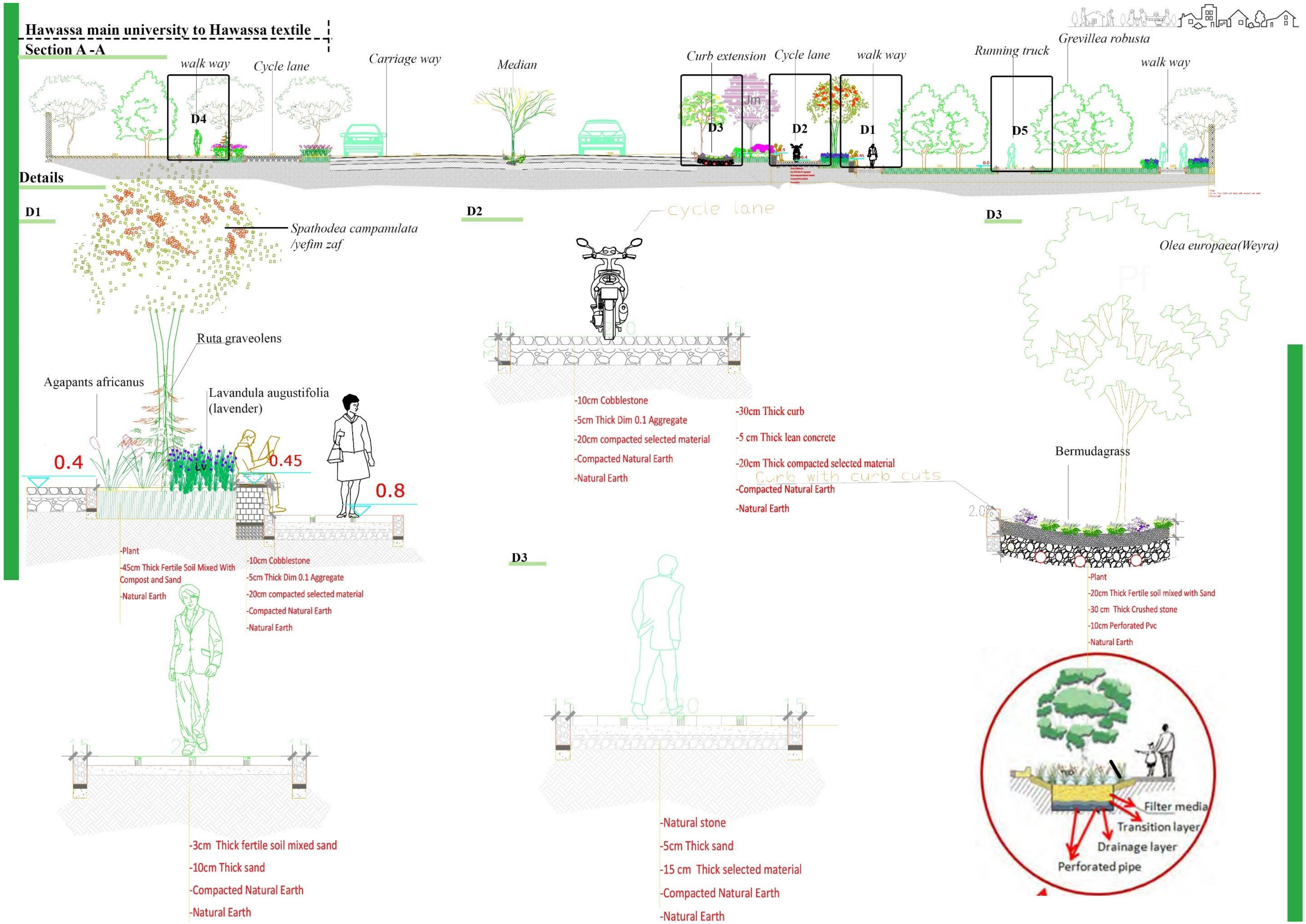
Existing Tree

*Existing street plan*




*section A-A*


Hawassa main university to Hawassa textile
Section A -A
walk way
Cycle lane
Carriage way
Median
Curb extension
Cycle lane
walk way
Running truck
Grevillea robusta
walk way
D4
D3
D2
D1
D5
Details
D1
Spathodea campanulata
/yefim zaf
Ruta graveolens
Agapants africanus
Lavandula augustifolia
(lavender)
0.4
0.45
0.8
-Plant
-45cm Thick Fertile Soil Mixed With Compost and Sand
-Natural Earth
-10cm Cobblestone
-5cm Thick Dim 0.1 Aggregate
-20cm compacted selected material
-Compacted Natural Earth
-Natural Earth
-3cm Thick fertile soil mixed sand
-10cm Thick sand
-Compacted Natural Earth
-Natural Earth
D2
cycle lane
-10cm Cobblestone
-5cm Thick Dim 0.1 Aggregate
-20cm compacted selected material
-Compacted Natural Earth
-Natural Earth
-30cm Thick curb
-5 cm Thick lean concrete
-20cm Thick compacted selected material
Curb with curb cuts
-Compacted Natural Earth
-Natural Earth
D3
-Natural stone
-5cm Thick sand
-15 cm Thick selected material
-Compacted Natural Earth
-Natural Earth
D3
Olea europaea(Weyra)
Bermudagrass
-Plant
-20cm Thick Fertile soil mixed with Sand
-30 cm Thick Crushed stone
-10cm Perforated Pvc
-Natural Earth
Filter media
Transition layer
Drainage layer
Perforated pipe

## Planting schedule

## Planting concept

Planting design based on ecosystem services and environmental value aims to optimize the benefits of plants in terms of structural stability, erosion control, pollutant removal, as well as social interaction, aesthetics, shade provision, and creating a sense of place. by including indigenous and exotic plants, grasses, trees, ground cover, shrubs, and herbaceous plants.

## Proposed Plants

-Each species is planted line and species change in every 30m interval

-Each species planted in every 10m interval

### Pedestrian Walkway Trees

*Podocarpus falcatus (zegeba)*

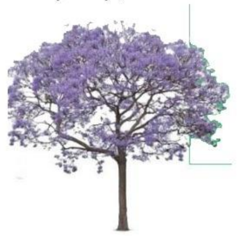
*Ficus benjaminia*

*Shinus molle(Kondo berbere)*

*prunus africana(Tikur einchent)*

*Spathodea campanulata/yefim zaf*

*Jacaranda mimosifolia( Yetmnja zaf )*



*Acacia saligna*

*Olea europaea(Weyra)*

*Acacia abyssinica (Girar)*

*Callistemon citrunus /bottle brush*

*Hiiscous rosanicous*

Acacia melanoxylon/omedla

### Median Trees

-The species is planted in every 6m interval.

Phoenix reclenta (zenbaba)

cupressus pyramidalis

The selection of the proposed walkway and median plants was based on their ability to provide various ecosystem services, including air purification, climate regulation, Storm water management , and aesthetic value.
for ornamental species selected based on the ecosystem provision, easily spread and fast-growing plants, and growth in dry conditions for bioswale and rain garden plant.

### Pedestrian walkway ornamental plants

Zantedeschia aethiopica/

Saliva svlvestris/

Tagetes erecta/ marigold

Gazania rigens /meshe dehnaederu

Tanacetum parthenium/ karot abeba

Each species is planted in mass
Each species is planted line and species change in every 3m interval

### Rain garden and bioswale plant

crocosmia lucifer

Bermudagrass

Agapants africanus

Lavandula augustifolia (lavender)

Joe Pye Weed

### Median ornamental plants

Agapants africanus

Gazania rigens /meshe dehnaederu

Gernium

Each species is planted in mass
Each species is planted line and species change in every 3m interval

### Around sitting area

Thymus Vulgaris

Cymbopogon ciratus

Ruta graveolens

Salvia Rosmarinus

Lavandula augustifolia (lavender)

-Each species is planted in mass

### Ground cover

-Each species is planted in mass

Mentha

Oenothera lindheimeri

Impatiens spp.

succulent plants

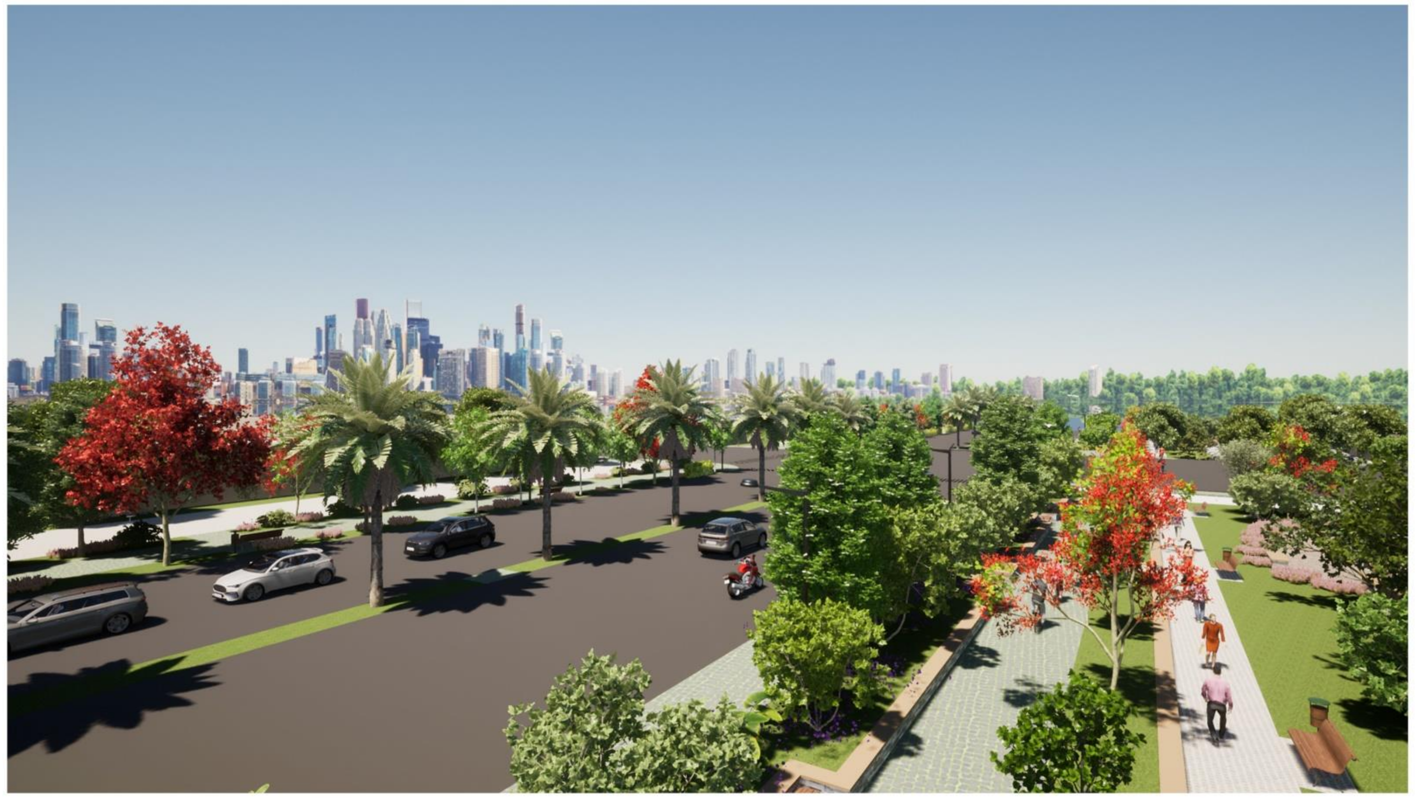
## 3D

### Proposed design

Carriage way

Pedestrian walk way

Cycle lane



Curb extension

Sitting area

Pedestrian walk way

### Existing condition

Pedestrian walk way

Carriage way

Open space left for green

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# Appendices

*Appendix A Article*

## Identify supply and demands of ecosystem provision from urban street trees in Hawassa.


## Abstract

*Urban trees offer a variety of advantages due to the variety of tasks they carry out. Street trees are an important component of urban and suburban that can change the way streets look and offer a variety of ecosystem service (regulating, provisioning, supporting, and cultural) benefits. However, Urban trees are highly influenced by people and other factors that negatively affect ecosystem service provision in addition to this when street trees are planted in Hawassa, this ecosystem service is not taken into account, and instead, the emphasis is placed on aesthetics, shade, and quickly growing plants rather than user demand and the ecosystem service provision by the street tree this lead to ecosystem service supply and demand imbalance. This study was conducted on five different street in Hawassa City and ecosystem services examined in this study are local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place. The objectives of the study are assessing* ecosystem service supply from urban street tree and investigate ecosystem service demand from urban street tree. *The study was conducted by collecting data from street user and by conducting observation on the selected street. In analyzing the data descriptive statistic for the questionnaire filled by street user and simple qualitative analysis is used for observation made on the street. Results indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, storm water management, and sense of place. Indicates that there is a significant gap between the provision of and demand for ecosystem services provided by street trees in urban areas. In general, the study forwards a recommendation for enhancing the current status of street tree and for future development and forwards new possible design prototypes that considers the demand of ecosystem provision to minimize the gap between supply and demand.*



**Keywords: urban street tree, Ecosystem service, supply, demand**

## 1. Introduction

The world is urbanizing at an unprecedented rate, with the United Nations projecting that 68% of the world's population will be living in urban areas by 2050 (United Nations, 2018). While urbanization has brought about significant benefits for humankind, it has also brought detrimental impacts on the environment and the ecosystem services provided (Seto et al., 2011)

Africa is currently undergoing a rapid urbanization process, leading to an urban fabric that is lacking those qualitative elements that combine to produce attractive built environments, provide public amenities, and enable a satisfactory urban lifestyle, with a low-quality of public space (UN Habitat III, 2014).

Ethiopian urbanization has witnessed significant growth in recent years, leading to various challenges in the urban environment,  As urbanization expands, there is often a loss of green spaces and natural habitats, leading to a decline in biodiversity (Mekonnen et al.,2018) moreover ,without properly planned environment the spaces have generated environmental problems, including temperature increases, air and water pollution, and greenhouse gas emissions (Molla, Ikporukpo and Olatubara, 2019). Hawassa town being one of the fastest growing urban centers in Ethiopia and its economic growth and developmental activities such as building, road construction, private residence expansion and many other anthropogenic activities have been on steadily increasing (Birhanu, 2020). Consequently, the vegetation of the area has been under enormous human impact and may be on the decline, Moreover The expansion of urban areas can lead to the urban heat island effect, where cities experience higher temperatures compared to surrounding rural areas (Tulu, Birara, and Gebretsadik., 2020) this impacts on the environment.

Urban Street trees play a crucial role in the development and maintenance of public green infrastructure in urban areas. Urban Street trees are an important component of urban and suburban that can change the way streets look and provide a range of ecosystem services that contribute to the well-being of both humans and the environment, street tree planting has been initiated to improve both human and ecological health(Winslow, 2021), including supporting services, mitigating services) and cultural services (Salmond et al. 2016).

The benefits of ecosystem services come with the upfront capital cost and (minimal) maintenance of natural solutions, such as planting trees. Trees provide many environmental benefits, and they exemplify how one natural component can harness several environmental and social benefis. While in the past, street trees have been essentially perceived as decorative elements (Sanesi and Chiarello, 2006), nowadays their environmental, economic, social, and aesthetical services and ecosystem service provision have been increasingly acknowledged (Millennium Ecosystem Assessment, 2005; Seamans, 2013). Human well-being is affected by gaps between ecosystem service supply and demand (Reid, 2005).

Unfortunately, Urban trees are subject to various factors that can lead to imbalances between the supply and demand of ecosystem services. These factors include human activities such as the presence of vehicles, buildings, pavements, utility lines, underground pipes, and animals, which can contribute to environmental issues. Additionally, natural, and social factors such as invasive plants, climate change, development, air pollution, inadequate management, and other social factors can further complicate the provision of ecosystem services by urban trees (Birhanu, 2020).

The gaps between the supply of ecosystem services and human demand can arise due to various factors, including land use changes, ecosystem degradation, climate change, and population growth (Yao et al., 2022), Rapid urbanization and limited space in urban areas can restrict the planting and growth of street trees, reducing their capacity to provide ecosystem services (Nowak et al., 2013). Furthermore, when planting street trees in Hawassa, the focus is often primarily on aesthetics, shade, and fast growth, rather than considering user demand and the provision of ecosystem services by the trees. This approach neglects the crucial role that street trees play in addressing environmental challenges and meeting the needs of users. Studies have highlighted that street trees are often selected for their visual appeal and fast growth, with ecosystem services being secondary considerations (Kirkpatrick et al., 2012; Conway, 2016). In addition, there is a knowledge gap regarding street trees and their role in providing ecosystem services. There is a clear lack of studies in sub Saharan Africa on exploring how to provide optimized use of trees tuned to the local natural conditions, socio-cultural context, and governance structures (Tan & Jim, 2017; duToit et al. 2018).

. Therefore, the objectives of this study are.

- To identify ecosystem service supply from urban street tree
- To investigate ecosystem service demand from urban street tree

*Conceptual framework*

The conceptual framework of this study is based on the ecosystem services cascade (ESC) model, which illustrates the relationship between the ecological structure-process and the benefits to human welfare derived from street tree ecosystem provision. The ESC was initially proposed by (Haines-Young and Potschin.,2010), and it serves as a chain structure that connects landscape structural processes and the resulting benefits (Andersson-Sköld *et al*., 2018).

The method employed in this study aims to be applicable ecosystem service assessments, and understanding the current or potential services and values of urban street ecosystems is required. It allows for the estimation of supply-side and demand-side aspects of ecosystem services, as well as identifying the gap between them (Malinauskaite, L *et al*., 2021).

The cascade model (Andersson-Sköld et al. 2018) provides a mechanism for exploring the link between benefits and values from nature, ecosystem services and functional aspects of the vegetation. E.g. a city facing increased air temperatures benefits from shadowed streets, that is provided by the ecosystem service air temperature regulation which in turn is depending of a specific trees ability to provide shadow, based on its functional traits (Sjöman et al. 2015).

## 2.Materials and Methods

### *2.1. Study Area*

The research was carried out in Hawassa City Administration. Hawassa is a city located on the shores of Lake Hawassa on the fringes of the Great Rift Valley. located 273 km from

Addis Ababa, geographically located on the city lays between $6^{0}$55’0’’ to $7^{0}$6’0’’ latitude North and $38^{0}$ 25’0’’ to $38^{0}$ 34’0’’ longitudes east (Figure 14 ). Mean annual total rainfall and mean monthly temperature range from 1000 to 1400 mm and 12.6°C to 30.1°C, respectively (SNNPRS, 2005). The boundaries of Hawassa City are Lake Hawassa in the west, Oromia Region in the north, Wendogenet woreda in the east, and Shebedino woreda in the south. The area under the control of the city administration is 157.2 (sq. km), which is divided into 32 Kebeles and 8 sub-cities. The study was conducted in Hawassa town on different five street segment.

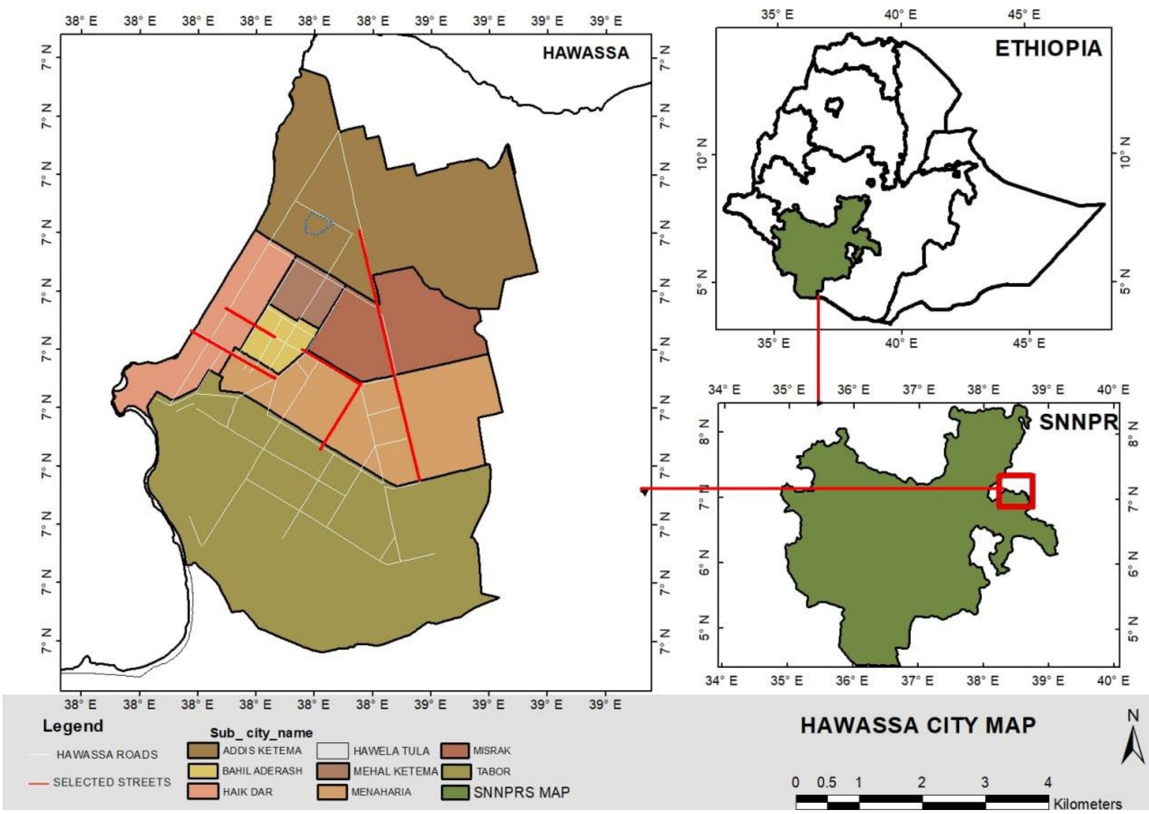


*Figure 14 location map*

## 2.2. Research design

To address the research objectives, the researcher utilized a mixed methodology approach that involved both qualitative and quantitative data collection techniques. questionaries, observation, and document review were employed as tools to gather data. This comprehensive approach allowed for a well-rounded and thorough data collection process, incorporating insights from multiple sources.

### *2.2. Types and Sources of Data*

In this research both primary and secondary data sources were used.

## 2.3. Sampling Design

### *Criteria's for Selecting Study Segments*

To achieve the intended objectives, a first preliminary survey was made to understand the overall condition of the street tree to identify ecosystem supply and demand to select the appropriate study sites. Moreover, the research was conducted around different areas of Hawassa, and the case selection was characterized by having, land use, street hierarchy and user traffic flow. The sampling sites was categorized into five different streets.

- From Tesfaye Gizaw to Atote meberat,
- From Tabour primary school to Hawassa agriculture university,
- From Hawassa main university to Hawassa textile
- South star hotel to wanza and
- From St.Gabriel church to Fikir lake

The three street from the inner-city zone and the other two from peripheral zone .

### *Sampling Techniques*

The study was designed to assess the existing condition of the urban street tree and identify their ecosystem service supply and demand. For this purpose, the researcher employed a sampling technique based on the purpose of the study, the need to reach the target tissue, and information gained during personal experience. For questioners the street users of the study area, the researcher used **simple random sampling,** who was available during the data collection.

### *Sampling population size.*

The data collected from various **street users, including pedestrians, cyclists, vendors, storefronts, and car users.** A simple random sampling was used to select individuals who passed through the street during the survey period. This approach helps to capture diverse perspectives and experiences of different street users. To determine the sample size for the participant respondents in the questionnaires, the researchers referred to the work of (Israel, 1992 ; Cochran 1977). They utilized a simplified formula for determining the sample size when the population size is unknown or infinite. A total of 378 questionnaires distributed approximately every 200 meters along the street, considering both side (Li, Wang and Huang, 2011). Based on the formula's the estimated number of people is 384 sampling. But successfully collect 378 sample from the respondents

## 2.4. Data collection method

**Observation/field assessment**: The observation data was conducted by the researcher to characterize and understand the existing condition of the study area and cross-check to add the data obtained through other methods of data collection. This method was applied to observe the existing urban street tree and current ecosystem service provision in the study area.

**Questionnaires**: The questionnaires are an essential tool for gathering primary data. Structured and pre-tested questionnaires were collected by using kobo collector tool from the respondent available during the study area. The questionnaires include closed and open-ended to get information about the research objectives. Various stakeholders who were related to the usage of the street tree ecosystem service provision were targeted by the survey questionnaire. They were **street users** (pedestrian, cyclist, vendors, car driver, storefronts).

The survey questions were prepared and coded in kobo collector tool and trained enumerators administered the survey between Feb and Mar 2023. The survey was conducted during different time gaps through the day to get different street user through the day. At the beginning of the survey, the purpose of the study was explained and consent to conduct the questionnaire was obtained. The survey questions were explained to the street users to make sure that they had understood them clearly. For assessing the ecosystem service supply provided by existing street trees, respondents were asked to rate them on a 5-point ordinal scale ranging from 5 (very good) to 1 (very poor). Similarly, for evaluating the ecosystem service demand of street trees on the selected street, the question was scored on a 5-point ordinal scale of 5 (very high) to 1 (very low). Additionally, the provision of streetscape elements was assessed using a 5-point ordinal scale ranging from 5 (very good) to 1 (very poor).

## 2.5. Method of Data Analysis and presentation

Both quantitative and qualitative techniques were used to analyze the data. The data collected through observation and questionnaire was analyzed by quantitative methods to interpret evidence through discussion and narration and for qualitative the collected data were initially coded in the Kobo Collector tool and then transferred to MS Excel for organization. The statistical analysis was conducted using SPSS 27 software. Descriptive statistical methods, such as means, frequency and percentages, were employed to summarize the scores obtained from respondents regarding their perception of the supply and demand of ecosystem service provision from street trees.

# 3. Results

## 3.1Selected Ecosystem Services

18 ecosystem services were selected for assessing in Hawassa city. These benefits were then categorized into eight groups of ecosystem services. These categories include local climate regulation (2 services), air quality regulation (3 services), stormwater management (2 services), aesthetic value (3 services), recreation and human health (4 services), biodiversity (2 services), food provision (1 service), and sense of place (1 service). The classification of ecosystem services assisted in structuring and comprehending the diverse range of services offered by the environment. Moreover, it aided in determining the supply and demand rates of these services, which are essential for recognizing their significance to the city.

## 3.2. Characteristic of respondents

Out of the 384 questionnaires dispatched by using kobo collector, 378 street users were willing to respond to the questions, resulting in a 98.4% response rate. About 59.5% of the respondent were male and 40.5% being female. Most respondents (62.4%) were between 18–30 years old, 27% between 31–64 years old, 6.1% were 60 years old and above and 4.5%were under 18. 22.2% of the respondents had no educational background, 7.9%had attained primary school, 9% had attained secondary education ,21.4% had attained certificate/diploma, 31% had attained degree and 8.5%had attained master's and above In terms of the type of respondent, 6.9% of the respondents described being car users, 11.1%

described being cyclists, and the majority of respondents (54.5%) described being pedestrians. About 13% of respondents described being street fronts, while 14.6% described being street vendors. As indicated in Table 23

*Table 23 Respondent demographic and other characteristics*

| Demographic and other Features | | Number (%) |
|---|---|---|
| Gender | Male | 59.5% |
| | Female | 40.5% |
| Age | under the age of 18 | 4.5% |
| | 18 and 30 | 62.4% |
| | 31 and 64 | 27% |
| | 65 years and older | 6.1% |
| Education level | No educational background | 22.2% |
| | Primary school (1-8) | 7.9% |
| | secondary school (9-12) | 9% |
| | Certificate diploma | 21.4% |
| | Degree | 31% |
| | Master's and above | 8.5% |
| type of respondent | Car users | 6.9% |
| | cyclists | 11.1% |
| | pedestrian | 54.5% |
| | Street front | 13% |
| | Street vendor | 14.6% |

### 3.3. Ecosystem service supply and demand

*Table 24 Ecosystem service supply and demand from Tesfaye Gizaw to Atote meberat*

| Ecosystem service categories | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 75 | 2.83 | 4.37 |
| | Shade provision | 75 | 3.40 | 4.11 |
| Air quality regulation | Dust removal | 75 | 3.27 | 3.51 |
| | Smoke free air | 75 | 3.55 | 3.37 |
| | Noise reduction | 75 | 2.84 | 3.77 |

| | | | | |
|---|---|---|---|---|
| Stormwater management | Flood runoff control | 75 | 2.72 | 4.29 |
| | Trapping Rainwater | 75 | 2.39 | 4.03 |
| Aesthetic value | Inspiration | 75 | 3.40 | 3.56 |
| | Availability of seasonal beautiful foliage tree | 75 | 3.52 | 4.08 |
| | Longer pavement life | 75 | 3.39 | 3.69 |
| Recreation and human health | Physical exercise | 75 | 2.69 | 3.79 |
| | Emotional and psychological health | 75 | 3.31 | 4.03 |
| | Social setting | 75 | 2.79 | 4.53 |
| | Space for recreation | 75 | 3.21 | 4.23 |
| Biodiversity | Tree species diversity | 75 | 3.05 | 3.85 |
| | Availability of birds and other wildlife | 75 | 2.76 | 3.31 |
| Food provision | Edible fruits | 75 | | 2.92 |
| Sense of place | Safe and familiar place | 75 | | 3.97 |

Interpretation of mean score: 4.21-5= very high, 3.41-4.20= high, 2.61-3.40 = medium, 1.81-2.60= low, 1-1.80 =very low

The survey results (Table 24) showed that most respondents believed that the first two parameters, Local climate regulation and Air quality regulation provision, were accessible or gained in a medium scale, with mean values ranging from 2.83 to 3.40, except for smoke-free air, which gained a good scale with a mean value of 3.55. The third parameter, stormwater regulation, was rated as medium for flood runoff control with a mean value of 2.72, and poor for trapping rainwater with a mean value of 2.39. The fourth parameter, Aesthetic value, was rated as good for availability of seasonal beauty foliage tree with a mean value of 3.52, and medium for longer pavement life with a mean value of 3.39. The fifth and sixth categories, Recreation and human health, and Biodiversity provision, were both rated as accessible or gained in a medium scale, with mean values ranging from 2.69 to 3.31.

The survey also found that current and future demands for ecosystem services were categorized into eight parameters (Table 4.17). The first category, Local climate regulation, including Thermal comfort and shade provision, had a mean value of 4.37, indicating that most respondents demanded thermal comfort at a very high level, while shade provision was demanded at a high level with a mean value of 4.11. The second category, Air quality regulation, including dust removal, smoke-free air, and noise reduction, had mean values of 3.51, 3.37, and 3.77, respectively, indicating that most participants agreed that these services were demanded at high, medium, and high levels, respectively.

The third category, Stormwater management, including flood runoff control and trapping rainwater, had mean values of 4.29 and 4.03, respectively, indicating that these services were demanded at very high and high levels. The fourth category, Aesthetic value, including inspiration, Availability of seas beauty foliage tree, and longer pavement life, had mean values ranging from 3.56 to 4.08, indicating that most respondents agreed that the demand for these services was high.

The fifth category, Recreation, and human health, including physical exercise, emotional and psychological health, social setting, and space for recreation, had mean values ranging from 3.79 to 4.53, indicating that most respondents agreed that the demand for these services was high to very high. The sixth category, Biodiversity, including Tree species diversity and Availability of birds and other wildlife, had mean values of 3.85 and 3.31, respectively, indicating that ecosystem provision was in high and medium levels.

The seventh category, Food provision, including cultivation of edible fruit for future demand, had a mean value of 2.92, indicating that most participants demanded it at a medium level. Finally, the eighth category, Sense of place, including Safe and familiar place, had a mean value of 3.97, indicating that most respondents demanded it at a high level.

*Table 25 Ecosystem service supply and demand from Tabor primary school to Hawassa agriculture university*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 75 | 3.29 | 4.04 |
| | Shade provision | 75 | 3.67 | 3.79 |
| Air quality regulation | Dust removal | 75 | 2.81 | 4.03 |
| | Smoke free air | 75 | 3.27 | 3.89 |
| | Noise reduction | 75 | 1.99 | 4.35 |
| Stormwater management | Flood runoff control | 75 | 1.36 | 4.81 |
| | Trapping Rainwater | 75 | 2.03 | 4.37 |
| Aesthetic value | Inspiration | 75 | 2.59 | 4.13 |

| | | | | |
|---|---|---|---|---|
| | Availability of seasonal beautiful foliage tree | 75 | 2.64 | 4.39 |
| | Longer pavement life | 75 | 1.81 | 4.57 |
| Recreation and human health | Physical exercise | 75 | 1.67 | 3.67 |
| | Emotional and psychological health | 75 | 2.41 | 4.07 |
| | Social setting | 75 | 2.09 | 4.65 |
| | Space for recreation | 75 | 2.48 | 4.53 |
| Biodiversity | Tree species diversity | 75 | 2.29 | 4.05 |
| | Availability of birds and other wildlife | 75 | 2.83 | 3.79 |
| Food provision | Edible fruits | 75 | | 3.01 |
| Sense of place | Safe and familiar place | 75 | | 4.15 |

Interpretation of mean score: 4.21-5= very high, 3.41-4.20= high, 2.61-3.40 = medium, 1.81-2.60= low, 1-1.80 =very low

A survey was conducted to assess the provision of ecosystem services by street trees. The results showed in (Table 25 )that most respondents believed that the first two parameters, which are Local climate regulation and Air quality regulation provision, were provided at a medium level. However, Shade provision was at a good level, and Noise reduction was at a poor level.

Regarding the third parameter, reducing flood runoff control by street trees was rated very poorly with a mean value of 1.36, while trapping rainwater was poorly provided with a mean value of 2.03, according to the survey participants.

For the fourth parameter, Aesthetic value, including inspiration, Availability of seasonal beautiful foliage trees, and longer pavement life, most respondents agreed that ecosystem services were poorly provided, with mean values of 2.59, 2.64, and 1.81, respectively. Except for the availability of seasonal beautiful foliage trees provided at medium level with a mean value of 2.64.

Regarding the fifth parameter, physical exercise was rated very poorly with a mean value of 1.67, while improving Emotional and psychological health, social setting, and space for recreation were all rated as poorly provided, with mean values of 2.41, 2.09, and 2.48, respectively.

For the sixth parameter, Tree species diversity and Availability of birds and other wildlife were rated as poorly and moderately provided with mean values of 2.29 and 2.83, respectively.

The survey indicated that most participants demanded high levels of ecosystem services from street trees. For thermal comfort and shade provision, most respondents demanded high levels, with mean values of 4.35 and 4.81, respectively. Dust removal and smoke-free air were demanded at high levels, with mean values of 4.03 and 3.89, respectively, while noise reduction was demanded at a very high level with a mean value of 4.35. Flood runoff control and trapping rainwater were both demanded at very high levels, with mean values of 4.81 and 4.37, respectively. Inspiration was demanded at a high level with a mean value of 4.13, while Availability of seas beauty foliage tree and longer pavement life were demanded at very high levels, with mean values of 4.39 and 4.57, respectively. Physical exercise and Emotional and psychological health were demanded at high levels, with mean values of 3.67 and 4.07, respectively, while social setting and Space for recreation were demanded at very high levels, with mean values of 4.65 and 4.53, respectively. Tree species diversity and Availability of birds and other wildlife were demanded at high levels, with mean values of 4.05 and 3.79, respectively. Edible fruit was demanded at a medium level with a mean value of 3.01, and Safe and familiar place was demanded at a high level with a mean value of 4.15.

*Table 26 Ecosystem service supply and demand from Hawassa main university to Hawassa textile*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 76 | 2.62 | 4.68 |
| | Shade provision | 76 | 2.87 | 4.55 |
| Air quality regulation | Dust removal | 76 | 2.50 | 3.79 |
| | Smoke free air | 76 | 2.89 | 3.86 |
| | Noise reduction | 76 | 2.37 | 4.20 |
| Stormwater management | Flood runoff control | 76 | 2.68 | 4.29 |
| | Trapping Rainwater | 76 | 2.37 | 4.30 |
| Aesthetic value | Inspiration | 76 | 2.95 | 4.04 |
| | Availability of seasonal beautiful foliage tree | 76 | 2.86 | 4.39 |
| | Longer pavement life | 76 | 3.37 | 3.62 |
| | Physical exercise | 76 | 2.82 | 3.74 |

| | | | | |
|---|---|---|---|---|
| Recreation and human health | Emotional and psychological health | 76 | 2.99 | 4.14 |
| | Social setting | 76 | 2.99 | 4.38 |
| | Space for recreation | 76 | 3.26 | 4.24 |
| Biodiversity | Tree species diversity | 76 | 2.51 | 4.46 |
| | Availability of birds and other wildlife | 76 | 2.79 | 3.61 |
| Food provision | Edible fruits | 76 | | 3.39 |
| Sense of place | Safe and familiar place | 76 | | 4.72 |

Interpretation of mean score: 4.21-5= very high, 3.41-4.20= high, 2.61-3.40 = medium, 1.81-2.60= low, 1-1.80 =very low

According to the survey results in (Table 26), there are eight different categories of ecosystem service supply and demand.

For Local climate regulation, the mean values for thermal comfort and shade provision were 2.62 and 2.87, respectively, indicating a medium level of provision. However, most participants demanded these services at a very high level, with mean values of 4.68 and 4.55, respectively.

For Air quality regulation, the mean values for removing dust from the air, reducing smoke, and noise reduction were 2.50, 2.89, and 2.37, respectively, indicating a poor to medium level of provision. Most participants demanded these services at a high level, with mean values of 3.79, 3.86, and 4.20, respectively.

For Stormwater management, the mean values for flood runoff control and trapping rainwater were 2.68 and 2.37, respectively, indicating a medium to poor level of provision. However, most participants demanded these services at a very high level, with mean values of 4.29 and 4.30, respectively.

For Aesthetic value, the mean values for inspiration, providing seasonal interest and natural beauty through foliage tree, and longer pavement life were 2.95, 2.86, and 3.37, respectively, indicating a medium level of provision. However, most participants demanded inspiration and Availability of seasonal beautiful foliage tree at a high to very high level, with mean values of 4.04 and 4.39, respectively, while longer pavement life was demanded at a high level with a mean value of 3.62.

For Recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.74, 4.14, 4.38, and 4.24, respectively, indicating a high to very high level of demanded but Most participants provision these services at a medium level with mean value 2.82, 2.99, 2.99 and 3.26, respectively.

For Biodiversity, the mean value of tree species diversity and availability of birds and other wildlife were 2.51 and 2.79, respectively, indicating this service was provided at a poor to medium level, however. the mean values for tree species diversity and availability of birds and other wildlife were 4.46 and 3.61, respectively, indicating a very high and high level of demand.

For Food provision, the mean value for edible fruit was 3.39, indicating a medium level of demand. Finally ,For Sense of place, the mean value for safe and familiar place was 4.72, indicating a very high level of demand.

*Table 27 Ecosystem service supply and demand from south star hotel to wanza*

| Ecosystem service | Perceived Benefits | N | Supply Mean | Demand Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 74 | 2.91 | 4.77 |
| | Shade provision | 74 | 3.31 | 4.42 |
| Air quality regulation | Dust removal | 74 | 3.23 | 3.58 |
| | Smoke free air | 74 | 3.23 | 3.86 |
| | Noise reduction | 74 | 2.31 | 4.23 |
| Stormwater management | Flood runoff control | 74 | 2.39 | 4.64 |
| | Trapping Rainwater | 74 | 2.64 | 4.49 |
| Aesthetic value | Inspiration | 74 | 3.69 | 3.70 |
| | Availability of seasonal beautiful foliage tree | 74 | 3.34 | 4.55 |
| | Longer pavement life | 74 | 3.69 | 3.54 |
| Recreation and human health | Physical exercise | 74 | 3.05 | 3.88 |
| | Emotional and psychological health | 74 | 3.36 | 4.05 |
| | Social setting | 74 | 3.32 | 4.26 |
| | Space for recreation | 74 | 3.45 | 4.12 |
| Biodiversity | Tree species diversity | 74 | 3.14 | 4.11 |
| | Availability of birds and other wildlife | 74 | 2.65 | 3.80 |
| Food provision | Edible fruits | 74 | | 2.59 |

| | | | | |
|---|---|---|---|---|
| Sense of place | Safe and familiar place | 74 | | 4.15 |

Interpretation of mean score: 4.21-5= very high, 3.41-4.20= high, 2.61-3.40 = medium, 1.81-2.60= low, 1-1.80 =very low

The survey results in (Table 27 showed that the 78 participants had varying opinions on the provision and demand of ecosystem services provided by street trees.

For Local climate regulation, the mean values for thermal comfort and shade provision were 2.91 and 3.31, respectively, indicating a medium level of provision. Most participants believed that there was not enough tree shade provision. However, the majority of participants demanded a very high level of thermal comfort and shade provision, with mean values of 4.77 and 4.42, respectively.

For Air quality regulation, the mean values for removing dust from air, reducing smoke, and noise reduction were 3.23, 3.23, and 2.31, respectively, indicating a medium to poor level of provision. Most participants demanded these services at a high to very high level, with mean values of 3.58 and 3.86 for dust removal and smoke-free air, respectively, and a mean value of 4.23 for noise reduction.

For Stormwater management, the mean values for flood runoff control and trapping rainwater were 2.39 and 2.64, respectively, indicating a poor to medium level of provision. However, most participants demanded these services at a very high level, with mean values of 4.64 and 4.49, respectively.

For Aesthetic value, the mean values for inspiration, Availability of seasonal beautiful foliage trees, and longer pavement life were 3.69, 3.34, and 3.69, respectively, indicating a good level of provision. However, the Availability of seasonal beautiful foliage trees was provided at a medium level, with a mean value of 3.34. Most participants demanded inspiration, Availability of seasonal beautiful foliage trees, and longer pavement life at a high to a very high level, with mean values of 3.70, 4.55, and 3.54, respectively.

For Recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.05, 3.36, 3.32, and 3.45, respectively, indicating a medium to good level of provision. Most participants demanded these services at a high level, except for space for recreation were demanded at very high level with mean value 4.26

For Biodiversity, the availability of different tree species diversity and habitat for birds and urban fauna, were provided at a medium level with mean values of 3.14 and 2.65, respectively. the mean values for tree species diversity and availability of birds and other wildlife were 4.11 and 3.80, respectively, indicating a high level of demand.

For Food provision, the mean value for edible fruit was 2.59, indicating a low level of demand.

For Sense of place, the mean value for safe and familiar place was 4.15, indicating a high level of demand.

Overall, the survey indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, and stormwater management.

*Table 28 Ecosystem service supply from St.Gabriel church to Fikir lake*

| Ecosystem service | | N | Mean | Mean |
|---|---|---|---|---|
| Local climate regulation | Thermal comfort | 78 | 3.32 | 3.86 |
| | Shade provision | 78 | 3.54 | 3.63 |
| Air quality regulation | Dust removal | 78 | 3.94 | 3.06 |
| | Smoke free air | 78 | 3.71 | 3.21 |
| | Noise reduction | 78 | 2.87 | 3.94 |
| Stormwater management | Flood runoff control | 78 | 2.88 | 4.22 |
| | Trapping Rainwater | 78 | 2.83 | 3.81 |
| Aesthetic value | Inspiration | 78 | 3.95 | 3.64 |
| | Availability of seasonal beautiful foliage tree | 78 | 3.63 | 4.12 |
| | Longer pavement life | 78 | 3.90 | 3.23 |
| Recreation and human health | Physical exercise | 78 | 3.37 | 3.45 |
| | Emotional and psychological health | 78 | 3.88 | 3.35 |
| | Social setting | 78 | 3.74 | 3.74 |
| | Space for recreation | 78 | 3.72 | 3.49 |
| Biodiversity | Tree species diversity | 78 | 2.96 | 3.92 |
| | Availability of birds and other wildlife | 78 | 3.09 | 3.04 |
| Food provision | Edible fruits | 78 | | 3.18 |
| Sense of place | Safe and familiar place | 78 | | 3.85 |

Interpretation of mean score: 4.21-5= very high, 3.41-4.20= high, 2.61-3.40 = medium, 1.81-2.60= low, 1-1.80 =very low

The study analyzed the provision and demand of ecosystem services across eight parameters, namely Local climate regulation, Air quality regulation, Stormwater management, Aesthetic value, Recreation and human health, Biodiversity, Food provision, and Sense of place. The mean values of the responses of 78 participants for each parameter were recorded in (Table 28).

For Local climate regulation, the mean values for thermal comfort and shade provision were 3.32 and 3.54, respectively, indicating a medium and good level of provision. Most participants demanded a high level of these services, with mean values of 3.86 and 3.63, respectively.

For Air quality regulation, the mean values for removing dust from air and reducing smoke were 3.94 and 3.71, respectively, indicating a good level of provision. The mean value for noise reduction was 2.87, indicating a medium level of provision. Participants demanded these services at medium to high levels, with mean values of 3.06 and 3.21 for dust removal and smoke-free air, respectively, and a mean value of 3.94 for noise reduction.

For Stormwater management, the mean values for flood runoff control and trapping rainwater were 4.22 and 3.81, respectively, indicating a very high and high level of demand. These services were categorized as medium level of provision at respected places on the street.

For Aesthetic value, the mean values for inspiration, Availability of seasonal beautiful foliage tree, and longer pavement life were 3.95, 3.63, and 3.90, respectively, indicating a good level of provision. Participants demanded inspiration and availability of seasonal beauty foliage tree at a high level, with mean values of 3.64 and 4.12, respectively, while longer pavement life was demanded at a medium level with a mean value of 3.23.

For Recreation and human health, the mean values for physical exercise, emotional and psychological health, social setting, and space for recreation were 3.37, 3.88, 3.74, and 3.72, respectively, indicating a medium to good level of provision. Most participants demanded these services at a high level, except for emotional and psychological health, which had a mean value of 3.35 indicating a medium level of demand.

For Biodiversity, the mean values for tree species diversity and availability of birds and other wildlife were 3.92 and 3.04, respectively, indicating a high and medium level of demand. Edible fruit was demanded at a medium level with a mean value of 3.18, while a safe and familiar place was demanded at a high level with a mean value of 3.85. These services were categorized as medium level of provision at respected places on the street.

## 4. Discussion

This study aimed to assess the supply and demand of ecosystem services provided by street trees. The survey results identified six segments of ecosystem service supply: Local climate regulation, air quality regulation, stormwater management, aesthetic value, recreation and human health, and Biodiversity. For Local climate regulation, shade provision was perceived to provide more service than thermal comfort. In other study street trees have been found to provide multiple benefits, including reducing air pollution, mitigating urban heat island effects, and enhancing the aesthetic quality of the street environment (Zhang et al., 2019). Street trees also provide shade, which can reduce the temperature of the pavement surface and make walking more comfortable for pedestrians. However, the availability of street trees in the studied street segments is under medium condition, with unplanned trees and a lack of spacing planning between trees in addition to this thermal comfort plays an important role in determining the quality of life in cities. The thermal comfort of urban pedestrians influences their choice and level of outdoor activities and the utilization of urban space (Huang, Lin, and Lien, 2015). In other study urban thermal environment is influenced by ground cover, including vegetation cover and impervious surfaces, as well as the geometry of street canyons (Johansson, 2006), In terms of air quality regulation, smoke-free air provision was in medium condition, while noise reduction service was rated as poor. The study found that the provision of noise reduction by street trees was perceived to be at a poor level by respondents, while the Barcelona study found that street trees provide noise reduction benefits. Another study by (Kabisch ., Frantzeskaki, and Hansen ,2022) found that urban residents expect trees to provide a range of benefits, including improving air quality and reducing noise levels, furthermore a study by (Tallis et al., 2011) street trees can be particularly effective at capturing airborne pollutants in urban areas. For stormwater management, reducing raindrops and flow of runoff provision was perceived to be in poor condition. Some studies have indicated that tree plantings, green filter strips, rain gardens, and bioretention swales are effective measures for controlling urban stormwater by reducing the volume and peaks of runoff (Marsalek et al., 1993). Regarding aesthetic value, ecosystem service provision from street trees perceived under medium condition. However, (Miller and Johnson .,2017) investigated the impact of foliage color on aesthetic value and discovered that trees with vibrant and contrasting foliage colors were perceived as more visually appealing Furthermore, (Smith et al. ,2018) conducted a survey among urban residents and found that the presence of street trees significantly enhanced the overall aesthetic appeal of streetscapes. In terms of recreation and human health, most parameters were rated as available at a medium scale, except for physical exercise, which was rated as poor, while other studies have found that access to green spaces and street trees can promote physical activity (Kaczynski et al., 2014).However , Another study by Kabisch ., Frantzeskaki, and Hansen (2022) found that urban trees can provide important benefits for human health and well-being, but these benefits are often not realized due to inadequate management practices and planning.

For biodiversity, the provision of tree species diversity and availability of birds and other wildlife under medium conditions, while a study by (Shashua-Bar et al.,2015) found that urban residents value the biodiversity and ecosystem services provided by trees in urban areas. Similarly, a study by( Yang et al., 2020) found that increasing tree species diversity in urban areas can provide important benefits for urban biodiversity and ecosystem services.

The survey also assessed the current and future demands of ecosystem service by including eight different parameters. For Local climate regulation, thermal comfort was in high demand, while shade provision during hot summers was in high demand. A study by Jim and Chen (2018) found that the demand for urban trees to provide shade and cool urban environments is high in hot and dry regions, but the provision of these services is often inadequate due to poor tree management practices and lack of investment in tree planting and care. For instance, a study by (Pauleit et al.,2019) found that urban trees are important for regulating urban microclimates, but their effectiveness varies depending on the species, location, and management practices. For Air quality regulation, dust removal, smoke-free air, and noise reduction services were in high demand. Some Studies have indicated that vegetation, including trees, can significantly reduce dust levels in urban environments, improving air quality and reducing potential health risks (e.g., Grote et al., 2016; Yang et al., 2020). For Stormwater management, flood runoff control and trapping rainwater were in very high and high demand, respectively also in Some study suggests that effective stormwater management is crucial in urban areas to mitigate the negative impacts of intense rainfall events. Various stormwater management techniques, such as green infrastructure (e.g., rain gardens, bioswales) and permeable pavements, have been shown to effectively manage stormwater by promoting infiltration, reducing runoff, and improving water quality (Wright and Ogden, 2016; Li et al., 2019).For Aesthetic value, inspiration, availability of seas beauty foliage tree, and longer pavement life were in high, very high, and high demand, respectively. A Study by (Hartig et al., 2014) found that the presence of trees and green spaces enhances the aesthetic appeal of urban environments. Trees provide visual beauty, adding color, texture, and natural elements to the landscape. Studies have shown that people perceive tree-lined streets and green spaces as more aesthetically pleasing, contributing to a positive perception of the overall environment. For Recreation and human health, physical exercise, emotional and psychological health, social setting with people, and space for recreation were in high, high, very high, and high demand, respectively, while other studies have found Access to green spaces, including areas with street trees, has a profound impact on recreation and human health. In terms of physical exercise, street trees provide shaded areas that invite people to engage in outdoor activities such as walking, jogging, and other forms of exercise. Studies have shown that the presence of street trees encourages physical activity and promotes an active lifestyle (Kaczynski et al., 2008; Sugiyama et al., 2008). Moreover, spending time in green environments, including streets lined with trees, has been scientifically linked to improved emotional and psychological health. These natural settings have a calming and restorative effect, reducing stress levels, enhancing mood, and benefiting overall mental well-being (Tyrväinen et al., 2014; Roe et al., 2013). Street trees also create attractive and welcoming social settings, fostering community engagement and social interactions. By providing pleasant spaces for people to gather, walk, and participate in recreational activities, street trees contribute to the development of social connections and a sense of belonging (Kuo et al., 2001; Ward Thompson et al., 2016). Furthermore, street trees play a vital role in providing spaces for recreation. They offer shaded areas that are ideal for relaxation, picnicking, and other leisure activities. This enhances the quality and appeal of urban environments, providing residents with accessible and enjoyable opportunities for recreation (Wolf, 2003; Fan et al., 2020). Biodiversity in urban areas, including tree species diversity and the presence of birds and other wildlife, is highly demanded. Research suggests that having a wide variety of tree species in urban environments can offer numerous benefits to biodiversity. This diversity provides habitats and food sources for various wildlife species, contributing to the enhancement of urban biodiversity and ecological resilience (Dearborn and Kark, 2010; Lerman et al., 2012) The demand for food provision through street trees, including the cultivation of edible fruit, is moderate. However, there are differing viewpoints regarding the suitability of street trees for food provision. One perspective argues against street tree food provision, citing concerns about cleanliness and hygiene. Research indicates that street trees can accumulate pollutants, such as heavy metals, from urban environments. This accumulation may pose a risk of contamination to the edible fruits they produce (Nowak et al., 2013; Dobbs et al., 2017). This viewpoint emphasizes the potential health risks associated with consuming fruits from street trees, raising concerns about the safety of such food sources. On the other hand, an opposing perspective argues in favor of street tree food provision, highlighting its potential benefits. Street trees can contribute to food security, particularly in urban areas with limited access to fresh produce. They provide a locally grown source of nutritious food and can promote community engagement and urban agriculture initiatives (Orsini et al., 2014; McClintock et al., 2016). Research supporting street tree food provision emphasizes the potential for increasing urban food production and enhancing community resilience. The demand for a safe and familiar place as part of the sense of place is consistently high. Several studies have explored the cultural and historical significance of street trees in specific contexts. They have found that street trees can symbolize heritage, traditions, and local identity, there by influencing the sense of place for residents and visitors (Beery and Jönsson, 2017; Kothencz et al., 2017). Furthermore, street trees contribute to a sense of identity and distinctiveness, making streets more recognizable and memorable. When well-maintained and diverse, street trees evoke positive emotions, enhance people's overall perception of the street, and encourage them to spend more time in the area.

## Conclusions

Urban street trees play a crucial role in providing essential ecosystem services that enhance the health and well-being of urban street user. However, in the city of Hawassa, there is a significant gap between the supply and demand of these ecosystem services. This study was conducted on five different street in Hawassa City and ecosystem services examined in this study are local climate regulation, air quality regulation, storm water management, aesthetic value, recreation and human health, biodiversity, food provision, and sense of place. This survey indicated that most participants demanded a very high level of ecosystem services provided by street trees, especially for local climate regulation, air quality regulation, storm water management, and sense of place. Indicates that there is a significant gap between the provision of and demand for ecosystem services provided by street trees in urban areas. Finally, the study forwards a recommendation for enhancing the current status of street tree and for future development and forwards new possible design prototypes that considers the demand of ecosystem provision to minimize the gap between supply and demand. In general, further study needs on identifying the most effective ways to provide these ecosystem services and how to balance the supply and demand of these services in urban areas.

## Recommendation

- When planting a street tree, it is important to consider a range of ecosystem services (ES) it can provide, rather than only focusing on its aesthetic value. Planting decisions should prioritize the multiple benefits that street trees can offer to the urban environment.
- Understanding the supply and demand of ecosystem services provided by street trees. It helps inform decisions regarding tree species selection, planting locations, and maintenance practices to maximize the benefits of street trees for both the community and the environment.
- When developing street tree initiatives, it is crucial to consider the community's demands and preferences regarding street trees.

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*Appendix B List of tree species recorded from Tesfaye gizaw(wanza) to Atote meberat*

| Species Name | Local Name | Family | Indigenous/ Exotic | Origin Deciduous / Evergreen | Right Side | Media | Left Side | Total number of trees | Proportion of trees% |
|---|---|---|---|---|---|---|---|---|---|
| Acacia abyssinica | Bazra girar | fabaceae | indigenous | evergreen | | | 2 | 2 | 0.81 |
| Araucaria biramulata | | Araucariaceae | Exotic | evergreen | | 39 | | 39 | 15.73 |
| Azadirachta indica | Kinin/neem | Meliaceae | Exotic | evergreen | 9 | | 7 | 16 | 6.45 |
| Callistemon citrinus | Bottle brsh/red | Myrtaceae | Exotic | evergreen | 21 | | | 21 | 8.47 |
| Callistemon salignus | Bottle brsh/white | Myrtaceae | Exotic | evergreen | 4 | | 2 | 6 | 2.42 |
| Cordia africana Lam. | Wanza | Boraginacea | indigenous | evergreen | | | 16 | 16 | 6.45 |
| cupresus lustanica | cypress tree | cupressaceae | Exotic | evergreen | 1 | 38 | | 39 | 15.73 |
| Delonix Regia | ye deredawa zaf | Fabaceae | Exotic | evergreen | | | 2 | 2 | 0.81 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 6 | | | 6 | 2.42 |
| Grevillea robusta | Grevillea | Proteaceae | Exotic | evergreen | 20 | | 20 | 40 | 16.13 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Jacaranda mimosifolia | Yetemenja zaf | Bignoniaceae | Exotic | deciduous | 11 | | 8 | 19 | 7.66 |
| Mangifera indica | Mango | Anacardiaceae | Exotic | deciduous | | | 2 | 2 | 0.81 |
| Moringa oleifera | Mimic | Moringaceae | Exotic | evergreen | | | 1 | 1 | 0.40 |
| Olea europaea | Woyra | oleaceae | indigenous | evergreen | | | 4 | 4 | 1.61 |
| Phoenix reclinata | Zenbaba | Arecaceae | Exotic | evergreen | | | 1 | 1 | 0.40 |
| Pinus patula | Pachula | Pinaceae | Exotic | evergreen | | | 2 | 2 | 0.81 |
| Podocarpus falcatus | Zigba | podocarpaceae | indigenous | evergreen | | | 1 | 1 | 0.40 |
| Schinus molle | Kondo berbere | Anacardiaceae | Exotic | evergreen | | | 2 | 2 | 0.81 |
| Senna marilandica? | Berbera | Fabaceae | Exotic | evergreen | 7 | | 15 | 22 | 8.87 |
| Terminalia brownii | Abalu | Combretaceae | Exotic | deciduous | 3 | | 3 | 6 | 2.42 |
| vernonia amygdalina | Gerawo | asteraceae | indigenous | evergreen | | | 1 | 1 | 0.40 |
| Total | | | | | 82 | 77 | 89 | 248 | |
| Sapling Tree | | | | | | | | | |
| Azadirachta indica | Neem | Meliaceae | Exotic | evergreen | 2 | | | 2 | 4.35 |
| Cordia africana Lam. | Wanza | Boraginacea | indigenous | evergreen | | | 12 | 12 | 26.09 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 8 | | 16 | 24 | 52.17 |
| Jacaranda mimosifolia | Yetemenja zaf | Bignoniaceae | Exotic | deciduous | 4 | | | 4 | 8.70 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Juniperess procera | Tid | cupressaceae | indigenous | evergreen | 1 | | | 1 | 2.17 |
| Phoenix reclinata | Zenbaba | Arecaceae | Exotic | evergreen | 1 | | | 1 | 2.17 |
| Terminalia brownii | Abalu | Combretaceae | Exotic | evergreen | 1 | | 1 | 2 | 4.35 |
| Total | | | | | 17 | | 29 | 46 | |

*Appendix C List of tree species recorded from Tabour primary school to Hawassa university college of Agriculture*

| Species Name | Local Name | family | Indigenous/ Exotic | Origin Deciduous / Evergreen | Right Side | Left Side | Total number of trees | Proportion of trees% |
|---|---|---|---|---|---|---|---|---|
| Acacia abyssinica | Bazra girar | fabaceae | Indigenous | evergreen | 1 | 2 | 3 | 1.88 |
| Araucaria biramulata | | Araucariaceae | exotic | evergreen | 3 | | 3 | 1.88 |
| Azadirachta indica | Kinin /neem | Meliaceae | Exotic | evergreen | 11 | 4 | 15 | 9.38 |
| combertom mole | | combretaceae | Exotic | deciduous | 1 | | 1 | 0.63 |
| Cordia africana Lam. | Wanza | Boraginacea | Indigenous | evergreen | 2 | 2 | 4 | 2.50 |
| Croton sylvaticus | Besna | Euphorbiaceae | Indigenous | deciduous | 1 | 1 | 2 | 1.25 |
| Delonix regia | ye deredawa zaf | Fabaceae | Exotic | evergreen | 2 | | 2 | 1.25 |
| Eucalyptus globulus | Nech bahir zaf | myrtaceae | Exotic | evergreen | 1 | | 1 | 0.63 |
| Grevillea robusta | Grevillea | Proteaceae | Exotic | evergreen | 34 | 54 | 88 | 55.00 |
| Jacaranda mimosifolia | Yeetemenja zaf | Bignoniaceae | Exotic | deciduous | 1 | | 1 | 0.63 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Phoenix reclinata | Zenbaba | Arecaceae | Exotic | evergreen | | 2 | 2 | 1.25 |
| Pinus patula | Pachula | Pinaceae | Exotic | evergreen | 1 | 1 | 2 | 1.25 |
| Schinus molle | Qundo berbere | Anacardiaceae | Exotic | evergreen | | 2 | 2 | 1.25 |
| Senna marilandica | | Fabaceae | Exotic | evergreen | 1 | 9 | 10 | 6.25 |
| Terminalia brownii | Abalu | combretaceae | Exotic | deciduous | 1 | 1 | 2 | 1.25 |
| bako plant | Bicha abeba | 12345 | Exotic | evergreen | 1 | 21 | 22 | 13.75 |
| Total | | | | | 61 | 99 | 160 | |
| | | | | | Sapling Tree | | | |
| | | | | | | | | |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 5 | | 5 | 100.00 |
| Total | | | | | 5 | | 5 | |

*Appendix D List of tree species recorded from Hawassa main university to Hawassa Textile*

| Species Name | Local Name | Family | Indigenous/ Exotic | Origin Deciduous / Evergreen | Right Side | Media | Left Side | Total number of trees | Proportion of trees% |
|---|---|---|---|---|---|---|---|---|---|
| Acacia abyssinica | Bazra girar | Fabaceae | Indigenous | evergreen | 1 | | 21 | 22 | 4.62 |
| Azadirachta indica | Kinin/neem | Meliaceae | Exotic | evergreen | 2 | | | 2 | 0.42 |
| Cordia africana Lam. | Wanza | Boraginaceae | Indigenous | evergreen | 5 | | 11 | 16 | 3.36 |
| Croton sylvaticus | Besna | Euphorbiaceae | Indigenous | deciduous | 11 | | 23 | 34 | 7.14 |
| Delonix regia | ye deredawa zaf | Fabaceae | Exotic | evergreen | 1 | | | 1 | 0.21 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 1 | | | 1 | 0.21 |
| Ficus vasta | Warka | Moraceae | Indigenous | evergreen | 4 | | | 4 | 0.84 |
| Grevillea robusta | Grevillea | Proteaceae | Exotic | evergreen | 1 | | 352 | 353 | 74.16 |
| Mangifera indica | Mango | Anacardiaceae | Exotic | deciduous | 1 | | | 1 | 0.21 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pinus patula | Pachula | Pinaceae | exotic | evergreen | | | 6 | 6 | 1.26 |
| Senna marilandica? | Berbera | Fabaceae | Exotic | evergreen | 8 | | 12 | 20 | 4.20 |
| Terminalia brownii | Abalu | Combretaceae | exotic | deciduous | 4 | | | 4 | 0.84 |
| | Koshem | | Indigenous | evergreen | | | 12 | 12 | 2.52 |
| Total | | | | | 39 | | 437 | 476 | |
| | | Sapling Tree | | | | | | | |
| Araucaria biramulata | Araucaria | Araucariaceae | Exotic | evergreen | | 104 | | 104 | 24.30 |
| Azadirachta indica | Neem | Meliaceae | Exotic | evergreen | 11 | | | 11 | 2.57 |
| Cordia africana Lam. | Wanza | Boraginacea | Indigenous | evergreen | 1 | | | 1 | 0.23 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 10 | 169 | | 179 | 41.82 |
| Nerium Oleander | Oleander | Apocynaceae | Exotic | evergreen | | 130 | | 130 | 30.37 |
| Persea americana | Avocado | Lauraceae | Exotic | evergreen | 2 | | | 2 | 0.47 |
| Terminalia brownii | Abalu | combretaceae | Exotic | deciduous | 1 | | | 1 | 0.23 |
| Total | | | | | 25 | 403 | | 428 | |

*Appendix E List of tree species recorded from south star hotel to wanza*

| Species Name | Local Name | Family | Indigenous/ Exotic | Origin Deciduous / Evergreen | Right Side | Media | Left Side | Total number of trees | Proportion of trees% |
|---|---|---|---|---|---|---|---|---|---|
| Acacia abyssinica | Bazra girar | Fabaceae | indigenous | evergreen | 1 | | | 1 | 0.35 |
| Araucaria biramulata | Araucaria | Araucariaceae | Exotic | evergreen | 10 | 11 | 2 | 23 | 7.99 |
| Azadirachta indica | Kinin/neem | Meliaceae | Exotic | evergreen | 8 | | 4 | 12 | 4.17 |
| Bogamvelia | Bougainvillea | Nyctaginaceae | Exotic | evergreen | | | 1 | 1 | 0.35 |
| Callistemon salignus | Bottle brush/white | Myrtaceae | Exotic | evergreen | | | 3 | 3 | 1.04 |
| combertom mole | | combretaceae | Exotic | deciduous | 5 | | 2 | 7 | 2.43 |
| Cordia africana Lam. | wanza | Boraginacea | indigenous | evergreen | | 1 | | 1 | 0.35 |
| cupresus lustanica | cypress tree | cupressaceae | Exotic | evergreen | | 2 | | 2 | 0.69 |
| Delonix Regia | yederedawa zaf | Fabaceae | Exotic | deciduous | | | 3 | 3 | 1.04 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 8 | | | 8 | 2.78 |
| Ficus elastica | Ye goma zaf | Moraceae | indigenous | evergreen | | | 3 | 3 | 1.04 |
| Grevillea robusta | Grevillea | Proteaceae | Exotic | evergreen | 29 | 1 | 41 | 71 | 24.65 |
| Hibiscus crassinerviusHochst | Ticha chenger | Malvaceae | indigenous | evergreen | 6 | | | 6 | 2.08 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Jacaranda mimosifolia | Yeetemenja zaf | Bignoniaceae | Exotic | deciduous | 1 | | 2 | 3 | 1.04 |
| Nerium Oleander | oleander | Apocynaceae | Exotic | evergreen | 6 | | | 6 | 2.08 |
| Phoenix reclinata | zenbaba | Arecaceae | Exotic | evergreen | | 69 | 1 | 70 | 24.31 |
| Schinus mole | Qundo berbere | Anacardiaceae | Exotic | evergreen | | | 2 | 2 | 0.69 |
| Senna marilandica | | Fabaceae | Exotic | evergreen | 32 | | 26 | 58 | 20.14 |
| Terminalia brownii | Abalu | Combretaceae | Exotic | deciduous | 3 | | 5 | 8 | 2.78 |
| Total | | | | | 109 | 84 | 95 | 288 | |
| Sapling Tree | | | | | | | | | |
| Araucaria biramulata | Araucaria | Araucariaceae | Exotic | evergreen | 1 | 3 | 23 | 27 | 28.72 |
| cupresus lustanica | Cypress tree | cupressaceae | Exotic | evergreen | | | 30 | 30 | 31.91 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | | | 4 | 4 | 4.26 |
| Phoenix reclinata | zenbaba | Arecaceae | Exotic | evergreen | | 25 | 8 | 33 | 35.11 |
| Total | | | | | 1 | 28 | 65 | 94 | |

*Appendix F List of tree species recorded from St.Gabriel church to Fikir lake*

| Species Name | Local Name | family | Indigenous/ Exotic | Origin Deciduous /Evergreen | Right Side | Media | Left Side | Total number of trees | Proportion of trees% |
|---|---|---|---|---|---|---|---|---|---|
| Araucaria biramulata | Araucaria | Araucariaceae | Exotic | evergreen | 3 | 46 | | 49 | 11.78 |
| Azadirachta indica | Kinin/neem | Meliaceae | Exotic | evergreen | 6 | | 4 | 10 | 2.40 |
| Callistemon citrinus | Bottle brsh/red | Myrtaceae | Exotic | evergreen | 3 | | | 3 | 0.72 |
| Callistemon salignus | Bottle brsh/ white | Myrtaceae | Exotic | evergreen | 13 | | 2 | 15 | 3.61 |
| Cordia africana Lam. | Wanza | Boraginacea | Indigenous | evergreen | 2 | | 5 | 7 | 1.68 |
| cupresus lustanica | cypress tree | cupressaceae | Exotic | evergreen | | | 4 | 4 | 0.96 |
| Delonix regia | yederedawa zaf | Fabaceae | Exotic | deciduous | 10 | | 2 | 12 | 2.88 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 4 | | | 4 | 0.96 |
| ficus sycomorus | Shola | moraceae | Indigenous | evergreen | 5 | | | 5 | 1.20 |
| Ficus vasta | Warka | Moraceae | Indigenous | evergreen | 1 | | | 1 | 0.24 |
| Grevillea robusta | Grevillea | Proteaceae | Exotic | evergreen | 23 | | 8 | 31 | 7.45 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Jacaranda mimosifolia | Yeetemenja zaf | Bignoniaceae | Exotic | deciduous | 78 | 1 | | 79 | 18.99 |
| musa acuminata | banana tree | musaceae | Exotic | evergreen | | 6 | | 6 | 1.44 |
| Nerium Oleande | Oleander | Apocynaceae | Exotic | evergreen | 26 | | | 26 | 6.25 |
| Olea europaea | Woyra | oleaceae | Indigenous | evergreen | 1 | | | 1 | 0.24 |
| Phoenix reclinata | Zenbaba | Arecaceae | Exotic | evergreen | 4 | 114 | | 118 | 28.37 |
| Pinus patula | Pachula | Pinaceae | Exotic | evergreen | 5 | | 4 | 9 | 2.16 |
| Podocarpus falcatus | Zigba | podocarpaceae | Indigenous | evergreen | 1 | | | 1 | 0.24 |
| polyalthia longifolia | Indiana tree | Annonaceae | Exotic | evergreen | | 14 | | 14 | 3.37 |
| Schinus mole | Kondo berbere | Anacardiaceae | Exotic | evergreen | 3 | | | 3 | 0.72 |
| Terminalia brownii | Abalu | Combretaceae | Exotic | deciduous | 8 | | 10 | 18 | 4.33 |
| Total | | | | | 196 | 181 | 39 | 416 | |
| Sapling Tree | | | | | | | | | |
| Araucaria biramulata | Araucaria | Araucariaceae | Exotic | evergreen | | 20 | | 20 | 21.74 |
| Ficus benjamina | | Moraceae | Exotic | evergreen | 31 | | 17 | 48 | 52.17 |
| Juniperus procera | Yehabesha Tid | cupressaceae | Indigenous | evergreen | | | 3 | 3 | 3.26 |
| Nerium Oleander | Olender | Apocynaceae | Exotic | evergreen | 4 | 1 | 1 | 6 | 6.52 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phoenix reclinata | Zenbaba | Arecaceae | Exotic | evergreen | | 1 | | 1 | 1.09 |
| polyalthia longifolia | Indian tree | Annonaceae | Exotic | evergreen | | 14 | | 14 | 15.22 |
| Total | | | | | 35 | 36 | 21 | 92 | |

*Appendix G List of interview respondents*

| Respondent Code | Gender | Department | Position | Total work experience | Work Experience in the position | Educational Qualification |
|---|---|---|---|---|---|---|
| 01-01 | Male | Hawassa city development and construction Bureau | Experts of city beautification and urban infrastructure development | 10 years | 3 years | MSc in urban management |
| 02-01 | Male | “ | Expert in green development | 20 years | 5 years | BA in business management, MSc in Geography |
| 03-01 | Male | “ | office head | 12 years | 8 years | Bsc Geography &environment studies, Msc urban environment and climate change management MSc |
| 04-01 | Male | “ | Expert in green development | 7 years | 4 years | BSc civil engineering |
| 05-01 | Male | “ | Ex office head | 30 years | 10 years | 12+4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 06-02 | Male | Municipality service standard expert | Team leader | 18 years | 14 years | BSc plant science and technology, MSc Agri resource and management |
| 07-02 | Male | “ | Expert in Land fill management | 10 years | 5 years | MSc environmental &climate change management |
| 08-03 | Male | Hawassa infrastructure and construction office Bureau | Team leader | 15 years | 12 years | BA Architecture |
| 09-03 | Male | Governmental project design and construction directorate | Expert | 8 years | 8 years | BA Architecture |
| 10-03 | Female | Governmental project design and construction directorate | Expert | 10 years | 6 years | BA Architecture |

EiABC
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**Questionnaire for street users**

*This questionnaire is prepared as part of a study that is undertaken as a partial fulfillment of the requirement for the degree of Master of Landscape Architecture program at the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC). The questionnaire is prepared to find out the supply and demands of ecosystem services from urban street trees, and design through a nature-based solution for Long-term ecosystem service provision.in Hawassa city. I kindly request your honest answers, so that the study reflects the fact. Thank you, for your kind cooperation.*

**Select one street segment that you are most familiar with**

**i.** Tesfyagezazwo(wanza ) to Atote

*ii. Tabor primary school to Hawassa agriculture university*

**iii.** Hawassa university to Hawassa textile(shell)

**iv.** south star to Wanza

**v.** st.Gabriel church to Fikir lake

**A. Demographic and General Assessment questions**

1. Gender a) Male b) Female
2. Age a) Below 18 b) 18 - 30 c) 31-64 d) 65 and above
3. Educational Status a) No educational background b) Primary school completed (1-8) c) High school completed(9-12) d)Certificate/diploma e)Degree f) Master's Degree and above
4. Occupation a) Unemployed b) Employed c) Private Business d) Student.
5. Type of respondents (street users)
   a) Pedestrian
   b) Street fronts
   c) Street Vendor
   d) Cyclists
   e) Car user
6. How often do you come here?
   a) Daily b) Once a week c) Twice per week d) Three times

per week e) Once a month f) Other?

7. For what purpose do you come here? (Multiple selection allowed)
   a) Walking
   b) Shopping
   c) Education
   d) Work/business
   e) Recreation /Visiting
   f) Appointment
   g) Other________

**B. Ecosystem Service Supply Assessment**

8. In your perception, how well are the following ecosystem services being supplied by street trees in Hawassa? (1 = very poor, 2 = poor, 3= Medium, 4= Good, 5 = Very Good)

| Ecosystem service | Ecosystem Service Category | Benefits / Values provided | Very poor | poor | Medium | Good | Very good |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Regulating services | Local climate regulation | Thermal comfort | | | | | |
| | | Shade provision | | | | | |
| | Air quality regulation | Dust removal | | | | | |
| | | Smoke-free air | | | | | |
| | | Noise reduction | | | | | |
| | Storm water management | Flood/runoff control | | | | | |
| | | Trapping Rainwater | | | | | |
| Cultural service | Aesthetic value | Inspiration | | | | | |
| | | Availability of seasonal beauty foliage tree | | | | | |
| | | Longer pavement life | | | | | |
| | | Physical exercise | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Recreation and human health | Emotional and psychological health | | | | | |
| | | Social setting | | | | | |
| | | Space for recreation | | | | | |
| | Biodiversity | Tree species diversity | | | | | |
| | | Availability of birds and other wildlife | | | | | |

**C. Ecosystem Service Demand Assessment**

9. In your perception, how well are the following ecosystem services demanded from street trees in Hawassa? If there are any other Ecosystem Services you demand, you may add them to the table. (1 = very low, 2 = low, 3= Medium, 4= high, 5 = Very high demand)

| Ecosystem service | Ecosystem Service Category | Benefits / Values provided | Very low | low | Medium | high | Very high |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Regulating services | Local climate regulation | Thermal comfort | | | | | |
| | | Shade provision | | | | | |
| | Air quality regulation | Dust removal | | | | | |
| | | Smoke free air | | | | | |
| | | Noise reduction | | | | | |
| | Storm water management | Flood/runoff control | | | | | |
| | | Trapping Rainwater | | | | | |
| | | Availability of drainage infrastructure | | | | | |
| Cultural service | Aesthetic value | Inspiration | | | | | |
| | | Availability of seasonal beauty foliage tree | | | | | |
| | | Longer pavement life | | | | | |
| | | Physical exercise | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Recreation and human health | Emotional and psychological health | | | | | |
| | | Social setting | | | | | |
| | | Space for recreation | | | | | |
| | Biodiversity | Tree species diversity | | | | | |
| | | Availability of birds and other wildlife | | | | | |
| Provisioning service | Food provision | Edible fruits | | | | | |
| Cultural service | Sense of place | Safe and familiar place | | | | | |

**D. Challenge and management assessment**

1. Have you encountered any of the listed challenge from urban street trees? (Multiple selection allowed)
   a) Tree branch falling
   b) Ugly trees with low maintenance level
   c) Blocking view
   d) Causing drainage problems
   e) Damage to property, buildings, and cars
   f) Obstructing use of space
   g) Hiding traffic signs and lighting
   h) none __________
   i) other
2. What are the key challenges of street tree development and management? (Multiple selections allowed)
   a) Wrong species selection
   b) Size of planting pits
   c) Compacted soil condition
   d) Space allocation
   e) Water availability
   f) Lack of skilled experts
   g) Lack of awareness among users
   h) finance
   i) none ________
   j) other
3. How do you evaluate the capacity and current practice of the city administration in developing and managing street trees?
   a) Very Poor b) Poor c) Medium d) Good e) Very Good

4. What solutions would you suggest for such challenges?

___________________________________________________________________________

___

E. **Streetscape Element Assessment**

1. How would you rank the streetscape element availability?

| streetscape element | | Very poor | poor | Medium | Good | Very good |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Street tree | Sidewalk tree | | | | | |
| | Median tree | | | | | |
| | Flower stands | | | | | |
| Street lighting | Street lighting system | | | | | |
| | Safety and security | | | | | |
| | Parking | | | | | |
| Street furniture | benches | | | | | |
| | signage | | | | | |
| | Trash cans | | | | | |
| Bicycle racks | Bicycle line | | | | | |
| | Bicycle parking | | | | | |
| | Perforation pavement | | | | | |
| | Comfortable for use | | | | | |

*Appendix I Interview Questions for the green expert*

**A : Personal background information**

1. Respondent code:
2. Gender: a) Male b) Female
3. Educational Qualification:
4. Specific work unit in the institution /organization:
5. Work experience

4.1 Total work experience:

4.2 Work experience in the current position:

**A. Current Practice**

B. In your perception, what factor being considered when determining the type of street tree species?
(1 = Very Low consideration, 2 = Low consideration, 3= Medium consideration, 4= High consideration, 5 = Very high consideration)

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| large Canopy size | | | | | |
| Aesthetics value | | | | | |
| stress resistance | | | | | |
| Ease of cultivation | | | | | |
| mass propagation | | | | | |
| infrastructure (overhead power lines, water and tele lines) | | | | | |
| branching pattern and texture, bark, leaves | | | | | |
| mature size | | | | | |
| autumn coloring | | | | | |

6. if you choose other option for the above question#6 please state it below.

7. How well are the following methods of street tree management being used?
(1 = Very Low ,2 = Low ,3= Medium ,4= High ,5 = Very high)

| | Very Low | Low | Medium | high | Very high |
|---|---|---|---|---|---|
| Watering | | | | | |
| tickling | | | | | |
| Pruning | | | | | |
| Cutting | | | | | |
| compost | | | | | |
| Security | | | | | |
| Fertilizer | | | | | |
| Protection | | | | | |
| Other | | | | | |

8. if you choose other option for the above question#8 please state it below

C. **Challenges of street tree Development**.

9. Have you encountered any of the listed challenges from urban street trees management what are the challenge from street tree management ?

(1 = Very Low ,2 = Low ,3= Medium ,4= High ,5 = Very high)

| | Very Low | Low | Medium | high | Very high |
|---|---|---|---|---|---|
| Tree branch falling and littering | | | | | |
| Ugly trees with low maintenance | | | | | |
| Blocking view | | | | | |
| Causing drainage problem | | | | | |
| Damage to property, building and cars | | | | | |
| Obstructing use of space | | | | | |
| Hiding traffic signs and lighting | | | | | |
| Lack of awareness among users | | | | | |
| Finance | | | | | |
| Lack of skilled experts | | | | | |
| Other | | | | | |

10. if you choose other option for the above question#9 please state it below.

11. What do you consider the main challenge for successful development of street tree that provide needed ecosystem services?

12. What kinds of strategies would you suggest mitigating these challenges?

13. What kind of challenges does your organization face after street tree development?

**D. Governance and Management of urban street trees**

14. Are there any policy documents, standards, local rules and regulations on the development and management of street trees? If yes, please clarify.

15. What organizations or actors are in direct relation with the planning, implementation, and management of urban street trees? To what extent is their influence on the matter?

16. Are there any staff, actors, or competencies needed or lacking that should be involved in the governance or management of urban street trees?

**E. Streetscape design**

17. Who is responsible for designing walkway roads?
18. What kind of profession is involved in walkway road design?
19. Is there a set of guidelines or a policy for designing streets? If yes, please clarify.
20. Do you take any streetscape elements into account when designing the road?
21. The interview is concluded. Do you have some final additional ideas to mention?

**Name of street segment Inventoried**

___________________________________________

- **Using base map, aerial photo of the area and Site visits**

1. Identifying trees species (scientific and local name) on each street segment
2. Identification of existing land use and dominating activities along the street segment
3. Major constraints of the current street tree development and challenges (street structure type)
4. Identification of site conditions (Water supply, ground cover, soil compactness, tree planting pits, landscaping)
5. Major Space allocation of a tree (street width, street space, gap between tree ,location of tree)?

- **Check list from Ecosystem Service Perspective**

| Ecosystem Services | Properties to be checked | Availability (Yes / No) | Observation Remark |
|---|---|---|---|
| Local climate regulation | Tree canopy size | | Large / Medium/Small |
| | Media Tree crown shape | | Large / Medium/Small |
| | Thermal comfort | | Good / Medium / Bad |
| | Shading of pavement, cars, and buildings | Yes / No | V.good/Good/Fair/Bad/Worse |
| Stormwater management | Availability of drainage infrastructure | Yes / No | V.good/Good/Fair/Bad/Worse |
| | Street permeability | Yes / No | V.good/Good/Fair/Bad/Worse |
| | Level of water/rain in the area | Yes / No | V. high, High / Medium / Low/v.low |
| Aesthetic value | Availability of seasonal beauty foliage tree | Yes / No | Good / Medium / Bad |
| | Planting pattern | Yes / No | V.good/Good/Fair/Bad/Worse |

| | | | |
|---|---|---|---|
| | Comfort for movement | | V.good/Good/Fair/Bad/Worse |
| | Visual aesthetics | Yes / No | V.good/Good/Fair/Bad/Worse |
| Recreation | Availability of street amenities under a tree | Yes / No | V.good/Good/Fair/Bad/Worse |
| | Space for recreation | Yes / No | V.good/Good/Fair/Bad/Worse |
| Biodiversity | Availability of birds and other wildlife | Yes / No | V.good/Good/Fair/Bad/Worse |

- **Checklist from Nature-based solution/streetscape element.**

| streetscape element | Parameters to be checked | Availability (Yes / No) | Condition (V.good, Good, Fair, Bad, Worse) | Observation Remark |
|---|---|---|---|---|
| Street tree | Trees (indigenous VS exotic) | Yes / No | | |
| | Plant diversity | Yes / No | | |
| | Median tree | Yes / No | | |
| | Flower stands | Yes / No | | |
| | Space allocation | Yes/No | | |
| | Planting location | Planned/unplanned | | |
| | Spacing between trees | Yes/no | | |
| | Space allocation | Yes/no | | |
| Street lighting | Street lighting system | Yes / No | | |
| | Safety and security | | | |
| Street furniture | Benches | Yes / No | | |
| | signage | Yes / No | | |
| | Trash cans | Yes / No | | |
| | seating | Yes / No | | |
| Bicycle racks | Bicycle line | Yes / No | | |
| | Bicycle parking | Yes / No | | |
| Pavement | Perforation pavement | Yes / No | | |
| | Comfortable for movement | | | |