Vertical Foresting: Innovative Solution for the Impacts of Fast City Growth on the Greenbelt of Adama City

Meseret Tesfaye Adane

A Thesis Submitted to the department of Architecture school of Civil Engineering and Architecture

Presented in partial fulfillment of the requirement for the Degree of Masters in urban planning and design

Office of graduate studies

Adama Science and Technology University

Adama, Ethiopia

June, 2022

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I the advisors of the thesis entitled **"Vertical Foresting: Innovative Solution for the Impacts of Fast City Growth on the Greenbelt of Adama City"** and developed by **Meseret Tesfaye** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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I the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled **"Vertical Foresting: Innovative Solution for the Impacts of Fast City Growth on the Greenbelt of Adama City"** prepared under my/our guidance by **Meseret Tesfaye** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in **Urban planning and Design.** Therefore, I/we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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TABLE OF CONTENTS

TABLE **PAGE**

LIST OF TABLES

TABLES **PAGE**

LIST OF FIGURES AND ILLUSTRATIONS

FIGURES **PAGE**

LIST OF ABBREVIATIONS AND ACRONYMS

Art	Article
ASTU	Adama Science and Technology University
CMP	Comprehensive Master Plan
CO_2	Carbon dioxide
EC	Ethiopian Calendar
EIA	Environmental Impact Assessment
ENVI	Environmental for Visualizing Images
EPE	Environmental Policy and Law of Ethiopia
EPE	Environmental Policy of Ethiopia
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
FDRE	Federal Democratic Republic of Ethiopia
GC	Gregorian Calendar
GI	Green Initiative
GIS	Geographic Information System
Ha	Hectare
LULC	Land use Land cover
LULCC	Land use and Land cover change
MSC	Manufacturing and Storage
MSE	Small and Micro Enterprise
MUDC	ministry of urban development and construction
ND	No date
NUGDS	National Urban Greenery Development Strategy
PhD	Doctor of Philosophy

ROI	Region of Interests
SBA	Stefano Boeri Architetti
SLC	Scan Line Corrector
SPSS	Statistical Package for the Social Science
SVM	Support Vector Machine
UIIDP	Urban Institutional and Infrastructure Development Program
UGI	Urban Green Initiative
UN	United Nation
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
Wi-Fi	Wireless Fidelity
WGS	World Geodetic System

ABSTRACT

Urbanization is a growth-promoting process that is a worldwide phenomenon that encourages economic progress and poverty reduction. As a process of urbanization, urban expansion has the potential to result in the loss of agricultural land, natural beauty, range areas, parks, and scenic views. Adama, from its territory coverage and population number, is among the cities that growing rapidly both in Oromia National Regional State and the Ethiopian rift valley regime. Thus, the city is under serious environmental degradation. In this research Adama city's growth was assessed to look at the impacts it had on the existing green belts surrounding the city namely land uses of agricultural lands, natural vegetative lands, and barren lands from the past 20 years. Then to provide an innovation mitigating solution for sustainability through the vertical foresting system by planning and designing an expansion city of vertical foresting. The research has valued the perception of the community in the city by using a stratified random sampling system. Here sample sizes were selected from each inventoried 18 kebele of the city randomly to make inferences for the entire population of the city. Informants were also addressed through in-depth interview. In this study, the researcher was primarily engaged in collecting field data which she had supported with secondary sources of information. For further evaluation of the impacts faced by those green belts Land Use/Land Cover change detection analysis was done to assess the spatial and temporal Land Use/Land Cover Changes in the city of Adama over the study period of the past 20 years (2000, 2007, 2014, and 2021) in four consecutive years each with an interval of 7 years apart. Remote sensing and GIS were used to provide land sat imageries of classified land classes (Urban-built area, Agricultural Land, Natural Vegetated areas, and Bare land) to map the changes that each land-use class has undergone. The results revealed that the city had exhibited significant change over the study periods by which the Land Use/Land Cover change detection showed the dramatic increase of urban built-up area from 999.45 Ha in the year 2000 to 4823.46 Ha in the year 2021 by which the surrounding green belts were over taken by the urban built-up areas. The collected data was presented by the use of both qualitatively and quantitatively. The research has therefore put planning and design solution that is believed to mitigate those impacts by creating urban forests through the system of vertical foresting on the selected expansion sites of the city of Adama in order to create awareness and become a base line for future studies and their implementation.

Key Words: ***Land Use/Land Cover Change, Urban Expansion, Vertical Foresting***

CHAPTER ONE

1. INTRODUCTION

This is a thesis conducted in Adama city of Oromia regional state, Ethiopia for the partial fulfillment of the requirements of the degree of master in urban planning and design at Adama science and technology university aimed at assessing the impacts of Adama city's growth on its surrounding greenbelt to provide an innovative solution through the recent concept of the vertical foresting system taking into consideration the environmental condition of the city.

City growth is a growing phenomenon across the world that is attributed to the city's social, economic, and environmental changes. As cities grow, they provide better economic, social, and life opportunities such as better jobs with better salaries and wages, better education and school with-well qualified facilities and teachers, better infrastructures, resources, and services for its inhabitants, and so on compared to their counterparts, rural areas, of the country. This is due to the certain case that describes a city's growth as a resulting phenomenon that emanates from the ills of its counterpart's countryside as people's movement towards cities in search of better lives is a frequent occurrence (Lamson-Hall, 2015).

The environment is subjected to growing land consumption, increased population, households, transportation facilities, and other factors that result in a reduction in available open spaces and vegetation cover since environmental problems are not fully addressed in the city of Adama (Disaster Risk Management Team, UIIDP, 2019). As an Architect, Urban planner and designer, and a permanent resident of Adama city, the researcher was aware of several aspects of this general situation. Therefore, the researcher is motivated to carry out more comprehensive investigations on the existing environmental condition of the city to better understand the changes occurring in the City's environment.

Thus, this is a chapter that describes the background of the study, the statement of the problems, the general and specific objective of the study, the research questions of the study, the scope of the study, the significance of the study, the limitation of the study and general description of the study area.

1.1. Background

The expansion of cities is a natural phenomenon linked to a variety of human activities, ranging from settling and building homes to constructing larger infrastructures and services (Selhausen, 2013). Cities have a competitive edge over rural regions in terms of productivity (Duranton, 2015). This is because cities are centers of knowledge and worldwide linkages, as well as magnets for population migration and economic development (Thomas, 2013).

Urbanization is a growth-promoting process that is a worldwide phenomenon that encourages economic progress and poverty alleviation or reduction. It is the supply of infrastructures such as housing, institutions, services and infrastructures, and recreational activities that are essential to locate activities in cities (United Nations, 2014).

Rapid urbanization is fueled by migration from both urban to urban and rural to urban areas, physical expansion of urban centers into surrounding rural and peri-urban areas, and natural growth of urban populations as a consequence of lower child and infant mortality rates. Large tracts of land from adjacent peri-urban areas are required for residential and other urban purposes as a result of extensive and ongoing urban population growth (Assefa et.al, 2020).

The process of urbanization or urban expansion, which can refer to both horizontal and vertical expansion of cities and urban area physical structures, is also known as urbanization. Urban expansion has the potential to result in the loss of agricultural land, natural beauty, range areas, parks, and scenic views (Firew, 2010).

Currently, more than 54% of the population of the world lives in urban areas which imply that by the year 2050, about 68% of the world's population will be living in cities, with Asia and Africa accounting for approximately 90% of this growth (Keno, 2019). According to the United Nations, growth is especially rapid in developing country cities. Sub-Saharan African countries are the least urbanized and populated in the world, with fewer than 40% of the population living in cities, but urbanization is accelerating in this region. According to UN estimates, the population of cities in developing nations would grow from 2 billion in 2000 to 4 billion in 2030 G.C. This will raise the percentage of people living in cities to roughly 87 percent, resulting in a rapid urban transformation (Geremew, 2017).

This rapid population increase in combination with the economic development has resulted in rapid urban physical growth and expansion, which, if not managed properly, can lead to serious negative environmental and socioeconomic issues. These issues include the urban

heat island effect, air pollution, loss of green space, loss of habitat, traffic congestion, insufficiency in infrastructure and services provision, and incompetent resource utilization, which countries with expected growth in their urban dwellers are particularly affected the most (Keno, 2019).

Ethiopia is among the world's countries with rapid urbanization and the fastest-growing population. In the next two decades, the number of people living in cities is predicted to nearly triple, from 15.2 million in 2012 to 42.3 million in 2037, expanding at a rate of 3.8 percent each year. According to the Ethiopia Urbanization Review (2015), the rate of urbanization would accelerate to around 5.4 percent per year by 2034, with 30 percent of the country's population living in urban areas by 2028 (UIIDP, 2018).

Ethiopia, even though is indeed one of the world's biodiversity centers is also one of the most damaged. Deforestation, soil erosion, biodiversity loss, and reductions in soil fertility and water quality are among the country's many environmental issues (Colby College Environmental Policy Group, 2011)

In terms of territory coverage and population number, Adama is the most populous city in the Ethiopian Rift Valley Regime. Adama is marked by rapid population growth, increased trade, and significant rural-urban mobility, all of which have contributed to the city's quick physical expansion and frequent change, according to the Adama municipality office (Disaster Risk Management Team, UIIDP, 2019).

According to the city administration of Adama, Adama has been dubbed one of the fastest-growing cities in Ethiopia with a great development potential because of the major contributing factors, them being: Its economic strategy and geographic location which gives it proximity to Addis Ababa, railway to Djibouti, High way to Harar, various Agro processing factories, mechanized farms such as sugar plantations, and the rich agricultural zones of Arsi and Bale; and its favorable climatic condition. These factors have attributed to the city's fast growth. as a commercial, industrial, residential and recreational center. This shows Adama is a hub for population increase because of its opportunities and advantages ("3rd Socio-Economic Profile of Adama City", 2018).

The expansion of urban areas is a space-consuming process in terms of the environment (Cocheci, 2014). Rapid urbanization in a country's big cities results in problems for long-term development since it draws energy and resources from far-flung ecosystems (Keno, 2019). As a result of this fast urbanization, the natural urban ecology has been disrupted, and

the urban environment has been damaged. The rapidly deteriorating environment in cities has prompted urgent research on urban forests, which can help to mitigate environmental degradation and improve the quality of life (Wang et al, 2018).

As a result, the Urban Forest Revolution is one of the environmental protection strategies that must be implemented, which is the establishment of environmentally friendly buildings (Architetti Boeri et al, 2018). Hence the creation of forests and other green spaces within cities is referred to as urban forestry (Visser, 2019). Among the ways, urban foresting can be implemented through the vertical foresting system. Vertical foresting is among the green movement's countries are engaged in to uphold and exercise sustainability. Vertical foresting is a model of environmental sustainability.

1.2. Statement of the Problem

Adama is among one of the primary cities of Ethiopia that has been dealing with problems associated with urbanization issues arising from different urban changes that result from their uncontrolled rapid growth. Therefore, the city of Adama has been subjected to severe environmental degradation as a result of the urban development as such residential, industrial, and commercial developments have displaced green areas. According to the study conducted by Berhanu Keno Terfa, Nengcheng Chen, Dandan Liu, Xiang Zhang, and Dev Niyogi (2019) Adama's population grew in practically every direction from the original metropolitan center. Rapid and dispersed pockets of urban land expansion were seen in the east, northeast, and southeast of the city between 2005 and 2017 (Keno, 2019).

In fast-growing cities, the increasing rate of urbanization has become a significant environmental concern. According to the Adama Green initiative (Adama GI) of 2020 by Muluneh Dhaabasaa of the Adama City Administration Municipality Office, Human congestion is expanding at an alarming rate in Adama from time to time as Adama has been growing both in spatial/physical terms and demographic terms. In Adama, due to the city's status and size, a balance between built-up areas and the natural environment has not been achieved ("Greenery Initiatives and Targets in Adama", 2020).

The environmental impact assessment (EIA) study report on the proposed landfill of Adama city has also mentioned: "There is undesired intervention accompanied by the ever-expansion of the city in all directions. These cause the over-consumption and destruction of the natural resources for housing and production of subsistence, Quarry exploitation, and establishment of infrastructures. Hence, the balance between environmental degradation,

and the development and protection of natural resources has not been kept" (Landfill EIA for Adama city solid waste landfill, (ND))

Hence different researches have shown that the city has been urbanizing rapidly and that built-up area is not balanced with natural environment which can be seen through the GI initiative of the city's achievements. The city is also deficient in balancing the rules of environmental protection with the ever-increasing environmental degradation.

The Adama GI (Green Initiative) from the Greenery Initiative and Target in Adama of the year 2020, Acquired from the Adama City Municipality office, has proposed a strategic plan for allocating urban land per the National Urban Greenery Development Strategy, which allocates 30%, 40%, and 30% of urban land to greenery, construction, and roadways, respectively. In Adama, the total acreage designated for urban greenery on the structural plan was 6,411.56 hectares, whereas the city's total administrative border area is 13,666.5 hectares. 2815.2 hectares of greenery are now covered. This means that the city of Adama has a greenery achievement of 20.7 percent. ("Greenery Initiatives and Targets in Adama", 2020). This shows that the city of Adama is working on a movement toward achieving a sustainable and ecofriendly living environment for its inhabitants.

Even though the city is in movement in urban greenery development initiatives it is still in a horizontal greenery expansion system. Which will still promoting land consumption to the surrounding ridges of the city. Thus, the aim of the research is to provide a link and integration of urbanization with sustainable development of the city through the environmental protection. It will also aim in reducing the rising land consumption of urbanization and provide insight on how to fulfill basic needs in a relatively limited area whilst growing or urbanizing hand in hand with the environment through the general system of building integrated with vegetation through vertical foresting.

There is insufficient information regarding building greenery integration as vertical foresting is an entirely new term to be implemented in the city of Adama. This research will be a bridge to combine the city, its growth, its population, and its environment.

1.3. Objective

1.3.1. General Objective

The overall research objective is to assess the impacts of Adama city growth on its surrounding greenbelt to provide an innovative solution through the vertical foresting system.

1.3.2. Specific Objective

- To identify the impacts of the Adama city's physical expansion on the existed greenbelt in terms of the Agricultural land, Natural vegetation, and Bare land of the city.
- To assess Adama city's growth through its physical expansion for the past 20 years by observing the land use and land cover change of the city.
- To develop a solution through the planning and design of a vertical foresting expansion city based on greenery provision.

1.4. Research Question

- What are the impacts faced by the surrounding greenbelt on the agricultural land, natural vegetation, and bare land due to the physical expansion?
- How much has the city of Adama physically expanded and altered its land during the past 20 years?
- How can the vertical foresting system be utilized as a solution for the impacts?

1.5. Significance of the Study

This research will work on creating a better understanding and awareness of the impacts that the growth trend of Adama city has on the green belt of the city to provide a better innovative and sustainable recommendation and design solution for the city of Adama and to promote further investigations and researches towards these issues not only for the city but also for other cities in the country.

The research will further look in-to the following aspects in order: To address the communities and the administrations awareness on growth trends of the city and what that trend has brought about on the environment; To better initiate the involvement of the city administration, other organizations, and the community in issues of the environment as environmental issues are not given attention as economic and social issues and educate that the environment is as important as the economic and social issues because looking in-to the long term it will become very difficult to undo the effects on the Environment and the nature; To introduce sustainability and environmentally friendly concepts in the form of vertical

foresting in integration with the countries and the city's available system of implementation; To create awareness on the fact that we are walking in the footsteps of the more developed nations which means we are not only dealing with the problems we are causing but also their left-over problems so it will not be so easy to fix what we are on the road of breaking so we need to act now; In order to pave the way for other studies concerning these issues for future application of sustainability.

1.6. Scope of the Study

The scope of this study focuses on assessing the impacts of Adama city's physical growth on the environment in the form of the green belt which includes agricultural land/farmland, bare land, and natural vegetation of the city to forward a sustainable solution recommendation in the form of vertical foresting system.

Spatially the study is confined to the city of Adama and fast expanded areas. Thematically the study will assess the growth trend of the city of Adama for the past 20 years and look into the impacts that it had brought onto the environment of the greenbelt surrounding the city to link it to the sustainable growth of the city. For the case of this research vertical foresting will be solely viewed and integrated in terms of greenery provisions.

1.7. Limitation of Study

The major limitation that the researcher faced was the current situation of the pandemic in the country because it made it difficult to move from place to place and to meet people required for different purposes in the research such as questionnaire purposes, interviews, and so on. The researcher was also faced with certain matters that could not be met through finance which included the availability of personal computers to accomplish some of the required work.

1.8. Organization of the Report

The research is divided into four main chapters in which the first chapter is concerned with background, Problem, Objective, Research questions, Significance, Scope and organization of the research, and operational definitions of the research. The second chapter is the literature part which deals with reviews of available and related documents. The third chapter deals with the methodology employed in the research while the fourth chapter and last chapter presents the result, discussion, the last conclusion, and recommendation forwarded by the researcher. The final part presents Appendixes and References.

1.9. Operational Definition

Urbanization – Urbanization is used to refer to the change in the land use for certain areas (generally on the outskirts of urban concentrations) because the land is ‘urbanized’ meaning the land is sold and further developed for urban purposes (e.g., the sale of plots for housing). It is a broad-based rural-to-urban change involving population, land use, economic activity, culture, or any combination of these (McGranahan et al, 2014).

Urban expansion – As a dynamic aspect of land change, urban expansion is a complex social/economic phenomenon. It could be linked to topographic, transportation, land use, social structure, and economic type information. It is the spread of people's attention to the surrounding land whose role is nonagricultural, and it is associated with urban sprawl. (Yimam, 2017).

Land use land cover change– The result of intricate interactions between humans and the surrounding physical environment, by which LULC involves the conversion of various land use categories (Yadav et al, 2019).

Sustainability – The foundation of sustainability is based on an ethical commitment to enhancing the well-being of not only current populations but also future generations' well-being and possibilities. It is a pursuit that works in balancing the three main goods i.e., ecological health, social equity, and economic welfare (Kibert et al).

Vertical forest – Vertical forests are living architectures and systems of environmental sustainability that set new urban ideals for bringing the human and natural worlds together in harmony (Architetti Boeri et al, 2018).

CHAPTER TWO

2. LITERATURE REVIEW

Theoretical Literature Review

2.1. Introduction

Cities are important centers that provide inhabitants with a varied selection of job, educational, and lifestyle options since they are great hubs for ideas, culture, science, productivity, commerce, and social development (FAO, 2018). In relation to their competitors, in the countryside and rural areas, cities can provide better surplus resources, better health care, better education, better work possibilities, and better lifestyles, all of which contribute to their rapid expansion.

Rapidly expanding cities are cities that are experiencing rapid growth. The term "city" is defined based on several criteria in different countries and regions, ranging from a single criterion such as population threshold to a combination of criteria such as population size, density, administrative delimitation, economic occupation, and so on (UN-HABITAT, ND).

Urban and rural communities are two types of human settlements. Different countries have varied descriptions of what an urban area is but most of these countries define an urban area in terms of its settlement density, population size, or the proportion of the population employed in the sector of agriculture. The Ethiopian and Liberian statistical offices define an urban area as a locality with more than 2,000 residents, from whom the majority of the inhabitants are not involved in agriculture. Because people are concentrated in a compact space rather than being spread over huge territories like rural areas and the fact that they are mostly engaged in non-agricultural activities, urban areas have higher population densities than the rural regions (Selhausen, 2013).

Cities previously were surrounded by large stretches of rural land. Rural populations are dwindling, while urban populations are steadily expanding, resulting in fast city expansion. The unsustainable urban expansion also causes other environmental and ecological issues (e.g., sparsity of green areas, deprivation of biodiversity, changing of landscape features, and so on.). This can be counterbalanced by the employment of urban greening programs in cities, which are a means to achieve ecological goals while minimizing the negative effects of urbanization (Pe´rez-Urrestarazu, 2015)

2.1.1. Urbanization

Human settlements are being transformed through the global process known as urbanization. The changing in regions, demographics, economies and the physical and built environment reflects the primary shift from rural to more urban societies (Seto et al, 2014). Which are the result of social, economic, and political events that lead to urbanization and the emergence of larger cities, changes in land use, and a shift in organizational and governance patterns from rural to metropolitan areas (Ambaye, 2012). One of the key driving causes behind the land-use change is urbanization. This lists the many types of land that are now in use (including urban, agricultural, and open land) (Wu et al, 2011).

2.1.1.1. Factors of Urbanization

Agricultural Revolution, Technological Revolution, Commercial Revolution, Increased Transportation Efficiency, and Demographic Revolution are five primary causes that influence city expansion and urbanization. Briefly described as **Agricultural Revolution**: The primary factor which was a prerequisite for the formation and growth of cities; **Technological Revolution**: The advent of mass manufacturing techniques, additionally the factory system, enabled the agglomeration of people in a densely settled pattern; **Commercial Revolution**: Cities were able to emerge as a result of the development of world marketplaces, exchange systems, and vastly better modes of transportation and communication; **Increased Efficiency of Transportation**: The transportation system is the lifeline of growing city life, as cities are the hub of trade. The expansion of transportation infrastructures resulted in the growth of today's cities due to the efficient provision of transportation let commodities and people move more rapidly and at lower costs from one location to another, both within the city and between the city and its hinterlands; **Demographic Revolution**: the different changes in the fields of agriculture, trade, industry, and transportation resulted in the change in demographics (Hussain et al, 2018).

Generally, two factors can be mentioned as well, the positive (Pull factors) and the negative (Push factors) that are accountable for the urbanization process. These factors can be generally described as the Agricultural revolution; demand for labor; developed or updated means of transportation and communication; civil facilities such as education, health, entertainment, and better housing condition; industrialization; developed health care services; secure life and living conditions; geographical and environmental factors; economic factors; infrastructural developments like banks and post offices; psychological

factors, employment opportunities; modernization and technological developments (Kushwaha, ND).

2.1.2. Urban Expansion

Urbanization, also known as urban expansion, is the process of increasing the spatial scale of a city (Yuan, 2007). The majority of urban expansion occurs mainly on the outskirts of cities and towns. The urban fringe is constantly redefining itself as the land cover expands which regularly redefines urban limits and what is classified as "urban" and "rural," resulting in a tangled web of linkage among the urban development, spatial growth, and urban administration (Avis, 2019).

The interaction among vertical growth (Increasing floor-to-area ratios as a consequence of increasing population and economic activity in key locations) and horizontal expansion (adding new settlements to more peripheral and outskirts of urban locations, with a modest vertical profile) characterized the urban expansion processes (Zambon et al, 2019). Horizontal urban expansion is commonly identified with urban sprawl, or the expansion of people or urban settlements to neighboring and surrounding areas, whose settlements have different purposes from those of cities (Firew, 2010).

Urban expansion of a city has been done both in a planned and unplanned manner by which the majority of commercial and industrial expansions were led by a planned system of urban expansion and many residential settlements resulted from the process of urban sprawl that occurred beginning of the inner cities towards the peripheries of the city in a form of informal settlements inbuilt and rented homes (Assefa et al, 2020).

Extension, infilling, and leapfrogging are ways by which an urban area can grow and develop (Keno, 2019). The majority of the blame for urban expansion is attributed to the costly leapfrogging of green-field development in which the development diminishes open space access and visibility. Due to the unplanned urban development, the sensitive environment and its habitants and the precious farm-lands are converted to urban lands. Because of the increased employment of cars, there is an increased level of dependency and promotion on automobiles making public transportation irrelevant and unattractive. It also necessitates lengthier and more expensive extensions of public infrastructure networks, as well as increased fees for residents of new expansion areas. It also keeps construction away from the city's key areas, which need to be renovated. All these will therefore result in an increased level of air pollution, energy use, and greenhouse gas emission (Ambaye, 2012).

2.1.2.1. Causes and Impacts of Urban Expansion

Spatial urban growth and an increase in urban population due to an increase in birth rate, as well as in-migration (from both rural to urban and urban to urban), are two primary causes of the expansion of urban to rural environments. This is because the sites that are located near and around urban areas are ideally necessitated for purposes of social, economic, industrial, and communication development, they are also ideal places for the construction of roads and other infrastructure and investment (Yimam, 2017).

According to the desk review conducted by William Robert Avis on Urban Expansion in Nigeria (2019), The main drivers or factors that lead to urban expansion are as follows: The difference between the number of births and the number of deaths referred to as the urban and natural increase; Migration from the countryside to the city termed as rural-urban migration; and Rural areas are being redefined into urban areas (Avis, 2019).

The lack of an environmental protection system precedes urbanization and urban expansion, resulting in pollution of the environment and the loss of agricultural land (Woldegebrel, 2017). According to Ahlam Yimam's 2017 research, the ability of urban centers to serve as market centers for the surrounding agricultural community, better access to both private and public services such as health, education, banking, postal, and telephone, better access to employment, and a modern way of life can be mentioned as the positive effects and impacts of urban expansion. The research also mentions the negative effects and impacts of such urban expansion as the displacement of farmers and degradation of valuable agricultural land, overexploitation of renewable and non-renewable resources, loss of natural assets, primarily land, and permanent declination of forest land (Yimam, 2017).

2.1.2.2. Land-Use/ Land-Cover Change

There are two distinct terminologies for land use and land cover change (LULC), which are frequently used synonymously. The biophysical aspects of the earth's surface, such as the distribution of plants, water, soil, and other physical features of the land, are referred to as land cover. While land use describes how humans and their habitat have used land, usually focused on the importance of land in economic activities (Yadav, 2019)

Changes in land cover and land use are referred to as land-use changes (Khare, 2010). The study of land-use and land-cover change (LULCC) is an environmental change study that is intimately linked to socioeconomic development. Urbanization is a global trend that has resulted in significant changes in land use/land cover (LULC). LULC changes are the

primary sources of worldwide environmental alteration (Tesema, 2020). The desire rather than the need or requirement to expand land use, either for agricultural or urban expansion purposes is the primary driving force for the change in land use and land cover (Jin Aik, 2021). Diverse natural and human elements, including social, economic, and political settings, influence land use and land cover changes (Oumer, 2009).

One of the key drivers of LU/LC change is population increase. A multitude of factors connected to human population increase, economic development, technology, and environmental transformations influence land-use changes. When land managers decide that a transition to a different land-use type is beneficial and desirable, land-use change occurs at the parcel level first. Conversion of land from one kind to another and adjustment of conditions within a category are reasons for land-cover changes. Natural processes (such as climatic and atmospheric alterations, wildlife, and pest infestation); Direct human activities (such as road, illegal housing construction, as well as deforestation (clearance of trees) and Indirect human activities (water diversion leading to drop in the water table), According to the United States Environmental Protection Agency (USEPA, 2004), are the prevalent causes of LU/LC changes (Belete, 2017).

Description of Land Use/Land Cover Classes

Urban Built-Up Area

"Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures. Cities, towns, villages, highway strip developments along the freeways, transportation, electricity, and communications facilities, and includes those activities by mills, shopping centers, industrial and commercial complexes, and institutions are all included in this category that may, in some instances, be isolated from urban areas" (Anderson, 1983). This class generally includes all regions with artificial or man-made surfaces, such as buildings and transportation infrastructure (asphalt, gravel, and railway) including construction areas (Tesema, 2020). The land in this category is covered by buildings of residence, commerce, services, industry, and mixed urban built-up lands (Rwanga, 2017)

Agricultural Land

Including areas for agriculture (both annuals and perennials) (Tesema, 2020). This category consists of a parcel of land that is primarily used for purposes of food and fiber production.

Agricultural land is land covered with interim crops which are succeeded by harvest periods (Rwanga, 2017). Agricultural land can be defined as a piece of land mainly used for food and fiber production, cropland and pasture land; orchards, groves, vineyards, nurseries, and ornamental horticultural areas; Confined Feeding Operations; other agricultural lands such as farmsteads, livestock holding areas such as corrals, horse farms, farm lanes and roads, ditches, and canals, small farm ponds, and others are the many categories mentioned in Agricultural land classes (Anderson, 1983).

Natural Vegetated Areas

The naturally vegetated land includes areas such as rangeland (grasses, grass-like plants, forbs, or shrubs), forest lands, and so on (Anderson, 1983). This category includes places with both native and exotic tree and shrub species. Green spaces in the urban built-up regions and environments are also included such as areas of grasses, trees, and other types of vegetation that are used for purposes such as beautification and recreation (Tesema, 2020)

Bare Land

Lands with bare soil, sand, or rocks that are never exceeding 10% vegetated at any time of the year are called Bare lands (Rwanga, 2017). These land categories mark areas that are not only without any plantation but also any type of crop, grass, trees, and other plants (Oumer, 2009). Bare lands are areas that have thinner soil, sand, rocks, and more extensively located vegetation if some are present (Anderson, 1983).

2.1.2.3. Remote sensing

Remote sensing is frequently used in conjunction with the Geographic Information System (GIS) (Rwanga, 2017). Both are basic devices to acquire more precise and convenient spatial data on land use and land cover for assessing the changes in the study area (Yadav, 2019).

A strategic system of collecting data and information for the air and space is defined as remote sensing. Remote sensing is the capability of gathering data without direct contact and direct involvement (Belete, 2017). Image classification systems are used to produce land use and land cover maps by remote sensing (Rwanga, 2017)

Images extracted from remote sensing can easily be used to capture land-use scenarios and provide an ideal source of data from which current LU/LC data and changes can be collected, evaluated, and simulated. As a result, remote sensing is frequently employed to identify and monitor land use at various scales (Yadav, 2019)

Various thematic and particular data on the required Land Use and Land Cover characteristics which are preconditions needed for the analysis of GIS data are acquired primarily from remote sensing. Ever since remote sensing and image processing software was introduced, remote sensing has become an important method in the field of GIS. Aerial and Landsat satellite images are commonly used to improve and adjust already existing geospatial characteristics and assess the Landcover distribution. Remote sensing data and techniques have become more and more advanced and complicated yet their use has made geospatial procedures fast and influential even if it has created more errors (Rwanga, S.S. & Ndambuki, 2017).

2.1.2.4. Geographic Information system (GIS)

"A Geographic Information System (GIS), is a computer-based system for capturing, storing, manipulating, analyzing, managing and displaying spatial or geographic data. In GIS, data types are divided into two categories: geographical (spatial) and non-spatial data. Spatial or geographic data are the data that have a location value while the non-spatial data are data that represent the spatial data in a tabular form" (Belete, 2017). Change detection requires a flexible framework for collecting, storing, displaying, and evaluating digital data which is achieved by Geographic Information System (GIS) (Yadav, 2019).

Contextual Review

2.2. Urbanization in Ethiopia

Ethiopia is one of Sub-Saharan Africa's fastest-growing countries. With a population of 102 million people, it is now Africa's second-most populous country, with a predicted population of 188 million by 2050 ("Labor and Social Office", 2019).

The Ethiopian planning law defines a city as "an 'urban center' with an established municipality or with a population size of 2000 or more inhabitants in which 50% of the labor force are Primarily engaged in non-agricultural activities" (Ermias, 2019). The Ethiopian Ministry of Urban Development and Construction (MoUDC) city-size classifications were also used to examine the variations and distributions of city size over time. The MoUDC (2012) divided cities into five distinct groups based on their size (Mezgebo, 2021).

According to the ministry of urban development and construction, the structural plan guide for classifying Ethiopian cities classifies urban areas through their city population status in such a way that 'small towns' are with people between 2000 to 20,000; 'medium towns' are between 20,000 to 50,000; 'large towns' are between 50,000 to 100,000; 'cities' are between

100,000 to 1,000,000 and ‘metropolis’ is above 1,000,000 (Ermias, 2019). By which the rise of early medium and large-sized towns owing to natural growth, as well as the merger of peri-urban/suburban regions into the respective towns, can be ascribed to the creation of cities (Mezgebo, 2021).

Even though the urbanization level of Ethiopia is low by African standards, the rate of its urbanization is unusual and uncommon. Until 1985, the country's growth rate was similar to that of Africa as a whole. Many African countries' growth rates have slowed significantly, whereas Ethiopia's development rate has been very quick in the recent two decades (Tsegaye, 2010).

Ethiopia is a country characterized by unplanned settlement expansion since different cities throughout the country have expanded over time by preparing comprehensive master plans (CMPs). These plans are plans that aim to coordinate and integrate the activities of diverse sectors and miss the point of providing what is desperately needed which is, land with a well-thought-out growth strategy (Hall, 2015).

Ethiopia is among the world's most important biodiversity hotspots, but it's also one of the degraded. Deforestation, soil erosion, biodiversity loss, and reductions in soil fertility and water quality are among the country's many environmental issues. These issues represent substantial dangers to Ethiopian inhabitants, as stated in Ethiopia's 1997 Environmental Policy (natural resources are the foundation of the economy) (Colby Environmental Policy Group, 2011).

Environmental degradation can both cause and worsen political, social, and economic problems. The environment is the primary source of income for a large portion of Ethiopia's inhabitants. This creates a vicious cycle of environmental degradation and poverty: individuals are “forced to disregard the environment's long-term well-being and thereby degrade it further” for their survival (Colby Environmental Policy Group, 2011).

2.2.1. Urban Expansion in Ethiopia

Ethiopia, as Africa's second-most populated country, has been undergoing a rapid urbanization process, since the implementation of economic development and privatization policies to drive national economic growth. The increased limitations are seen in many developing countries, such as unplanned and unregulated plans, resulting in scattered urban growth, agricultural loss, and environmental damage arising from a country’s rapid urbanization process. Furthermore, in Ethiopian cities, the rate of physical growth has

outpaced the rate of infrastructure and service delivery. Addis Ababa, Adama, and Hawassa have been the primary cities in Ethiopia suffering severe environmental degradation due to their rapid urbanization rate (Keno, 2019).

Migration is recognized as a fundamental driver in Ethiopia's urban growth and changes, resulting in significant growth in the country's urban population, which may occur in both rural to urban and urban to urban migrations. Another aspect of Ethiopian urbanization is driven by the transformation of villages into urban centers, as well as the expansion of urban areas into rural areas owing to urban sprawl (Ayele, 2020).

2.2.2. Environmental Policy and Law of Ethiopia (EPE)

Through the country's great concern for the environment, the constitution of (FDRE, The Environmental Policy of 1997) advances basic environmental policies to provide basic principles and guidelines with necessary policies to promote and elevate environmental protection and management (Vibhute, 1999).

FDRE Constitution-Environmental Spirit and Policy Principles

The FDRE Constitutions includes sets of '**Fundamental rights**' and '**Environmental objectives**' that show Ethiopia's profound concern towards its environment including some necessary policy-oriented principles and guidelines for purpose of management and protection of the environment (Vibhute, 1999).

A. Fundamental Rights

The FDRE Constitution guarantees the fundamental right to live in a clean and healthy environment, the right to livelihood, and the right to sustainable development (Vibhute, 1999) are presented as follows:

The Right to a Clean and Healthy Environment

Art 44(1) states that 'Everyone has the right to a healthy and clean environment'.

The Right to Livelihood

Art 44(2) of the Constitution guarantees a person who has been displaced or has lost a source of income as a result of government programs has the right to obtain adequate compensation from the government.

The Right to Sustainable Development

"The right to sustainable development, as globally perceived, refers to the development that meets the needs of the present generation without compromising the environmental needs of

its future generations. Art 43(4) reaffirms the core concept of sustainable development, namely, development based on the logical and wise use of natural resources.

B. Environmental Objectives

"The Constitution enumerates a set of 'environmental objectives through the prime concern of the Ethiopian Government for 'environment'. Art 92, listing these environmental objectives, reads":

1. "Government shall endeavor to guarantee that all Ethiopians live in a safe and healthy environment".
2. "The design and implementation of programs and projects of development shall not damage or destroy the environment".
3. "When it comes to the formation and implementation of environmental policies and projects that directly affect them, people have the right to full consultation and expression of ideas.".
4. "Government and citizens shall have the duty to protect the environment".

Environmental Policy

The Overall Policy Goal

The overall policy goal of the environmental policy encloses two main cases, them being, 'the improvement and enhancement of the health and quality of life of Ethiopians, and promotion of sustainable development.

The Specific Policy Objectives

More specific policy goals are forwarded under the specific policy objective of the EPE:

1. "To ensure that essential ecological processes and life support systems are sustained, biological diversity is preserved, and renewable natural resources are used in such a way that their regenerative capabilities are maintained and that the needs of future generations are not compromised"
2. "To ensure that the benefits of exploitation of non-renewable resources are also extended to the future generation"
3. "To prevent the pollution of land, air, and water in the most cost-effective way so that the cost of effective preventive intervention does not exceed the benefits"
4. "To ensure peoples' participation in the eco-management"
5. "To improve the environment of human settlements in such a manner that satisfies the physical, social, economic, and cultural needs of the inhabitants"

6. “To enhance public awareness and understanding about the link that exists between development and environment”

2.2.3. Adama City

2.2.3.1. Historical Background

Adama, according to the city's municipality, was founded almost a century ago, in the late nineteenth century. The Ethiopian empire is said to have made an inadvertent contribution to the city's emergence. The development of a strong foothold for the Ethiopian ground army in the city, the opening of the Addis Ababa to Djibouti railway in 1917, and the Italian occupation are just a few of the key factors. The first settlement of indigenous people to trade goods and services with railway workers was the beginning of the process that eventually led to the development of the area into a focal point as an urban area (Haile, 2019)

Adama, which is located in a strategic location along the vibrant transport corridor that connects the country's eastern and southeastern regions, was founded as a railway station beneath the Kechema ridge in 1917, 99 kilometers southeast of Addis Ababa, in an economically and geographically strategic location at the crossroads of major routes to Addis Ababa, Arsi, Harar, and other economically significant areas (“4th Socio-Economic Profile of Adama City”, 2019).

At first, considerable communities were concentrated along the railway line and on a low-lying area beneath the high ridge of Kechema immediately west of Adama, which subsequently evolved into a large city (“3rd Socio-Economic Profile of Adama City”, 2018). Before Adama sprawled in different directions and the city was able to hold the current shape in due course of time, the pattern of physical layouts of the city had gradually evolved to the east direction following the railway line that spanned from Djibouti to Finfinnee (Addis Ababa) (“4th Socio-Economic Profile of Adama City”, 2019).

Nowadays, the city's original starting quarter is nearly entirely located in the northwestern part of the city and is known as 'Adaama Duri' /'Aroge Adama'/, which means "old Adama" in English. It is now one of Adama's oldest sections (“3rd Socio-Economic Profile of Adama City”, 2018).

2.2.3.2. Adama City Growth

Adama city, like any other city in the developing world, has been the center of economic activity and transportation networks in Ethiopia and has been gradually expanding both geographically and in terms of its population (Sinha, 2016).

Adama, which is ideal for residence, tourism, trade, and manufacturing and serves as the region's administrative, commercial, manufacturing, and educational hub, has seen tremendous changes and served as a distribution center for the surrounding areas since its establishment due to its comparative advantages, which favored the city's rise and development as a population concentration, commercial, industrial, residential, and recreational center ("4th Socio-Economic Profile of Adama City", 2019).

Various combinations of encouraging and suitable circumstances have increased the city's long-term expansion. These factors include the availability of various untapped and untouched natural resources, the presence of four entry and exit points into and out of Adama, proximity to the metropolitan city of Addis Ababa (Finfinnee), and the city's economically strategic geographic and convenient location along eastern trade routes, which are 99 kilometers from Finfinnee (Addis-Ababa) and pass through the city ("3rd Socio-Economic Profile of Adama City", 2018).

Among the many factors contributing to the city's rapid growth the main ones include its close location to tourist attraction points of Sodare, Geregedi, Boku, its proximity to productive agricultural areas in Bale and Arsi, the wide extensions of very close secondary towns to it, the advantages of having commodities distribution and commercial centeredness roles of the city, accessibility to resources of construction materials with advantages in quality, and the city's proximity to River Awash, which carries water throughout the year and contributes a lot to the expansion of various industries that was established for the production of sugarcane, fruits, cotton, vegetables, and generating hydroelectric power, the availability of convenient basic economic and social infrastructure, and sufficient and efficient transportation facilities (railways and roads) that well connected the city to regions, zones, and other major towns in the country, fast trade movements and high transactions, the availability of convenient basic economic and social infrastructure, and the availability of sufficient and efficient transportation facilities (railways and roads) that well connected the city to regions, zones, and other major towns in the country ("3rd Socio-Economic Profile of Adama City", 2018).

As a result, Adama's history is distinguished by remarkable changes in the city's physical expansion, industrial institutions, housing development, and population, all of which have altered the city's appearance (Keno, 2019).

Theoretical Literature Review

2.3. Vertical Foresting

The United Nations' Bruntland Commission in 1987 defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Al-Kodmany, 2018).

Environmental and social concerns about urban expansion are jeopardizing human well-being and a city's long-term viability and sustainability. To address these issues sustainably and naturally, new urban greening concepts are being created (Pe´rez-Urrestarazu, 2015).

Sustainability refers to the relationship that humans have with their natural environment in terms of resource allocation, which should be done in a way that balances today's and future generations' resource needs. Among the many means of implementing sustainability, the urban forest revolution is one of them.

Stefano Boeri pioneered the Vertical Foresting technique in the city of Milan in 2014. The primary concept of vertical foresting is to give back to nature, which has inspired world-renowned architects to rethink farming as well. With the concept of "Trees in the Key," a sustainable method of vertical tree growth in residential buildings in metropolitan cities that adds to biodiversity was developed (Raj Kumar, 2017).

2.3.1. The Basis for Vertical Foresting

According to the article provided by Vera A. Akristiniy, and Yulia I. Boriskina called Vertical cities - the new form of high-rise construction evolution (2018) the following are put forward as some of the basic factors that influence the use of vertical foresting (Akristiniy, 2018):

1. The urban population is rapidly growing.
2. Population development causes cities to densify horizontally, resulting in enormous amounts of land consumption, vegetation loss, and the loss of abundant land.
3. Construction of industries and transportation facilities that release significant amounts of harmful waste into the environment.
4. The development of high-rise buildings at a breakneck pace.
5. The pressing need to safeguard the environment and work toward better resource allocation.
6. The rate of technical growth, transformation, and expansion in the cities are extremely high.

7. The inhabitants have an unquenchable desire for luxury and decent living conditions.

2.3.2. Vertical Forests

Vertical forests “A house for trees and birds, inhabited also by humans” Stefano Boeri Vertical Forest is a sustainable residential building concept and a scheme for urban forestry that contributes to the rehabilitation of urban areas, the ecosystem, and urban biodiversity without implying the city's expansion onto the land. It's a method of natural vertical densification inside the city that works with reforestation and naturalization policies at big urban and metropolitan boundaries. Vertical forests assist in the planning and design of environmentally friendly structures. It operates by connecting the artificial and natural environments to maintain the world's balance. The Vertical Forest is a densification and anti-sprawl initiative that aims to limit urban sprawl while increasing the amount of green space in the built environment (Boeri et al, 2018).

The vertical forest system allows the building to outperform the plant life that was removed from the ground for its construction. Different varieties of plants are employed as green walls and planted in areas such as balconies to give cleaner air without requiring a large amount of space, as cities are densely packed with skyscrapers and little open ground space. In densely populated areas, vertical forests help reduce carbon dioxide, nitrogen dioxide, and other toxic and damaging gases while also releasing more oxygen.

The trees and plants placed in vertical forests help to absorb carbon dioxide and suspended particulate matter which will, in turn, reduce the smog and create a buffer to reduce the noise pollution as well as reduce the heating effect around the building and the surrounding areas because of the transpiration of trees and plants creates a relatively cooler microclimate which requires less energy consumption for purposes such as artificial cooling. Vertical foresting nowadays considering the current condition of scarcity of land and space can be a healthy arbitration between sustainability and productivity because a single building can be helpful for the surrounding area (Saravanan, 2017).

2.3.3. Effects of Vertical Foresting on the Ecosystem

Different authors provided various insights on the advantages and the disadvantages of the vertical foresting systems which are briefly described below:

Advantages of Vertical Foresting

According to the short review paper provided by Raj Kumar Y and Ramya D called Vertical forests: real-time solution for the upcoming rise of air pollution in India (2017) the following are put forward as the pros of vertical foresting (Raj Kumar, 2017):

1. The Vertical Forest Ecosystem lowers world mean temperatures in both urban and rural areas, absorbing CO2 and photochemical pollution in the process
2. It also removes contaminants from the air and reduces fuel vehicle emissions
3. It increases biodiversity by providing habitat for and attracting a variety of animal species, such as birds, butterflies, and insects, to live in green infrastructures
4. By absorbing dust and pollution, green construction reduces high temperatures. Green walls operate as a natural heat insulator
5. They help in lowering the demand for energy as well and save energy by minimizing the need for additional artificial cooling or heating units in the building
6. It helps to reduce patient recovery time through biophilia by aiding in the healing of their physical, emotional, and social health concerns
7. They aid in the preservation of the site's natural ecology, scenery, and cultural legacy
8. They can also help the agricultural district by providing residents with a vertical farm to look after

According to the journal prepared by Prof. Rupali Goud, Nitesh Kumar Chauhan, Himanshu Lokhande, and Sanjay Bohre titled Vertical Forest to Clean Environment (2018) the following are also mentioned as advantages of vertical foresting (Goud, 2018)

1. Vertical foresting helps combat 'co_2 domes' which are invisible clouds that are created over urban areas
2. The plants absorb carbon dioxide and release oxygen to the surrounding by which plant foliage aid in the reduction of sound and traffic noises that come from the streets of cities.
3. Creates microclimates and combats the heat island effect in cities.
4. They create a visually appealing, safe, and healthy living environment for the inhabitants

Saravanan J, Jayadurgalakshmi M, and Karthickraja R also mentioned different benefits of vertical forests in their journal China's Nanjing Vs India's Delhi – A Perspective for Vertical Forest (2017) (Saravanan, 2017):

1. The natural photosynthesis and transpiration of the plants living in vertical forests improve the building's interior and outdoor air quality.
2. By providing a proper microclimate for the building and the surrounding area, they counteract the urban heat island effect created by plentiful buildings and diminished flora.

Disadvantages of Vertical Foresting

Some of the cons of vertical foresting mentioned by Raj Kumar Y and Ramya D in their short review paper Vertical forests: real-time solution for the upcoming rise of air pollution in India (2017) are as follows (Raj Kumar, 2017):

1. Vertical foresting adoption in cities necessitates exorbitant construction and maintenance expenditures
2. Pollination has become a critical component in the ecosystem's survival
3. The cost of labor is also skyrocketing

According to the journal prepared by Saravanan J, Jayadurgalakshmi M and Karthickraja R titled China's Nanjing Vs India's Delhi – A Perspective for Vertical Forest (2017) the following are put forward as some of the disadvantages of vertical forests (Saravanan, 2017):

1. Vertical foresting requires constant monitoring and new forms of gardeners, skilled laborers, and integration and combination of various ideas for environmental protection.
2. Vertical foresting requires special structural design, it also faces increased dead load in areas such as balconies where the plants are placed, and it also requires the design of irrigation and the attraction and spread of unwanted insects and so on.

2.3.4. Vertical Forest City

Vertical forest cities are one of the vertical foresting techniques that support the Urban Forest Revolution, which promotes building integration with their surroundings (Boeri et al, 2018).

Vertical forest cities are a hybrid of vertical cities and forest cities, intending to improve relationships between inhabitants and the natural environment by shifting urban growth from horizontal to vertical development. To improve the city's ecology and develop more green space they work in lowering the population pressure and energy consumption of the city. They also work in maintaining the city's health and resilience as well (Guan et al, 2018).

"Vertical cities are a collection of multi skyscraper cities that incorporate all the necessary facilities together and are interconnected by sky bridges while Forest cities are a collection

of vertical forests that incorporate green infrastructures such as plants and trees in their buildings" (Guan et al, 2018).

2.3.5. Building Integrated Vegetation in Vertical Foresting

Building greening systems and building integrated vegetation are two terms that can be used interchangeably which are terms used to describe the greening system and vegetating system of buildings (Ann Marugg, ND). These vegetated surfaces can drastically modify the microclimate surrounding them by incorporating gardening and vegetating systems with (grass, small crops, pergolas, or even trees) on the building elements, which can have an evident thermal effect on the entire city if done on an urban scale.

The BIV system comprises of green roofs and green walls, with the term "green" encompassing a wide range of meanings such as "living," "breathing," and "vegetation." From private to public scale, the BIV system in architecture provides significant "visual, social, economic, and environmental benefits" to the metropolitan region (Lee, 2014)

The building-integrated vegetation system can be achieved in two ways which are the vertical and horizontal greening systems (Wang, 2020). Vertical greening systems include systems that enable vegetation to extend across a façade or interior wall, and they are regarded as a sustainable/green building design method (Hui, 2017)

The following are the five most frequent types of building-integrated plants (Ann Marugg, ND).

Green Roof

Greening roofs can have a substantial impact at both the building and city scales because roofs account for 20-25 percent of total urban surface area. A green roof is made up of a variety of support layers that allow vegetation to grow on a flat or inclined rooftop. The plant layer, growing medium, filter, drainage (moisture retention), root barrier, and ultimately waterproofing membrane on top of a structural deck are the layers of a green roof from top to bottom (Raji, ND). A roof garden with often decorative vegetation or a fertile area that has been deliberately created to spread and grow naturally are two types of green roofs (Lee, 2014).

Green roofs are horizontal greening systems that are relatively lightweight allowing them to be used on many roofs without the need for structural strengthening (Wang, 2020). These are roofs having vegetated surfaces and subtract layers as roofs can account for up to 32%

of horizontal surfaces, rooftops, especially in metropolitan settings with limited space, can provide a considerable surface area for possible vegetation integration and in doing so the roofs are protected from incoming solar radiation by the flora and substrate layer, which has a higher albedo than ordinary black roofing materials. Green roofs are visually appealing, help clean the air, absorb the noise pollution from the surrounding, and safeguard biodiversity (Ann Marugg, ND).

Elevated Forests

Elevated forests are the other form of horizontal greening system is a collection of trees growing in a defined and sheltered horizontal space in the building forming a forest in the sky (Wang, 2020).

Green Wall

Green walls, also known as green façades, are a type of construction that uses plants to cover the vertical elements of buildings. The planting media is frequently placed on another surface, such as the ground or a container, rather than next to the architectural element (Lee, 2014).

Green-wall technologies, vertical gardens, and bio walls are all terms used to describe vertical greening systems (VGS), Which are made up of vertical structures that distribute vegetation and are attached to a building face or an interior wall (Pe´rez-Urrestarazu, 2015).

Green walls are a form of vertical greening system that are plants hanging down branches or modular plants (Wang, 2020). A regulated growth of plants is integrated into the vertical surface of a building to create a green wall. The term 'vertical garden' is sometimes used to describe greenery that grows vertically. A green wall could be installed either inside or outside the structure. Growing methods include green façades and living walls. Plants can grow upward or downward on the vertical surface (Hui, 2017)

- **Green Façade –** Plants anchored in the ground that climb the wall (conventional direct system) or other independent supporting systems or elements such as cables or meshes (double skin indirect system), wires, or trellis situated on or near the wall are examples of green facades (Wang, 2020). They are based on climbing plants that attached themselves directly to the building surface or are indirectly supported by cables or trellis (Hui, 2017).

Climbing plants or cascading groundcover provide the vegetative cover in green facade systems (green screens). Specially built buildings can be utilized to promote plant growth through the building's wall, which can then be used to support climbing plants. Green facades are often rooted in the ground or plant boxes at the base, but intermediary planters mounted to the wall at a specified height or on rooftops as a falling green cascade, can indeed be applied. Green facades require less upkeep and protection than living walls due to the reduced variety and quantity of plants (Pe´rez-Urrestarazu, 2015).

- **Living walls**

Built from modular panels, each with its soil or artificial growing medium (substrate-based or hydroponics) living walls can make it possible to incorporate greening into taller buildings and cover vertical surfaces quickly (Hui, 2017).

Living walls are a part of complicated infrastructures that include a supporting framework and several attachment mechanisms. To prevent dampness and moisture issues, a waterproof backing is essential to segregate the living wall from the building. Fertigation, monitoring systems, and lighting are optional., However, an irrigation system is required. (Pe´rez-Urrestarazu, 2015).

Sky Garden (Sky courts or podium gardens)

The word "sky garden" refers to the green space on a high-rise building's rooftop or intermediate floors. When a garden is located on an intermediate level, it is referred to as a platform (Podium) garden, and when it is located on the top of a building, it is referred to as a roof garden (Ann Marugg, ND).

A vegetated open area that is found at any elevation isolated from the ground level through man-made structures is known as a sky garden. These features can provide environmental and human benefits. Sky gardens are also green spaces above the ground surface that can take the shape of a podium garden on the building's intermediary floors or a roof garden on the roof (Raji, ND)

Indoor Sky Garden

Indoor sky gardens are multi-story indoor areas with potted plants or large trees in thick soil substrates, similar to atriums. Indoor plants provide some of the same benefits to building

occupants as outdoor nature experiences. One of the several advantages that indoor vegetation can give residents is improved comfort (Raji, ND)

A winter garden or a green atrium are other names for an indoor sky garden. The purpose of an indoor sky garden is frequently compared to that of an outdoor sky garden, with a focus on recreation and social interaction. However, it can provide advantages of creating a comfortable environment regardless of the exterior surrounding climatic conditions, as opposed to an outdoor sky garden (Ann Marugg, ND).

Green Balcony

Balconies can offer breathtaking views of the city, an urban park, or natural flora. Balconies can also serve as a transitional place between indoor and outdoor environments. They provide numerous benefits and advantages for both building occupants and the environment (Raji, ND)

A balcony is a platform that projects from a building's wall and is surrounded by a parapet or railing. A balcony is frequently referred to as a terrace, however, the phrase is misleading because the term terrace can also refer to a flat roof or paved area on the ground level. In scientific literature, the terms "green balcony" and "balcony garden" mainly relate to the installation of a greening module or potted plants on a balcony. Because the size of these plants is limited, their impact on the microclimate is similarly limited (Ann Marugg, ND).

Green Terraces

Green terraces are other ways of creating a vertical greening system in which plants are growing along the façade of horizontal terraces. These terraces are built on different heights and levels of the building (Wang, 2020).

Empirical Literature

2.4. Case Study

2.4.1. International Case Study

The Bosco Vertical

Figure 1: Bosco Vertical

Source: Google image

The Bosco Verticale is the world's first vertical forest, located in Milan. The Bosco Verticale is a building in Milan, Italy, that translates to "Vertical Forest." It was finished in October 2014 as a "vegetated skyscraper." The structure was created by Milanese architect Stefano Boeri in collaboration with architects Giovanni La Varra and Gianandrea Barreca as a project for Boeri's architectural firm Stefano Boeri Architetti (SBA). The building consists of two residential complexes with each tower having 26 stories (76 Apartments) and 18 stories (40 Apartments) with a height of 111 and 78 meters respectively. The façades are covered with plants, bushes, and trees (Visser, 2019).

Approximately 900 trees (each measuring 3m, 6m, and 9m meters) and more than 20,000 shrubs and flower plants, and plants of the varied range are scattered according to the light exposure of the facade in the residential complexes. Each Vertical Forest represents 20,000 square meters of forest in terms of the number of trees on flat land. It is the equivalent of almost 75,000 sqm of single-family housing in terms of urban densification (Architetti Boeri et al, 2018).

Figure 2: Bosco Verticale Photo Plan and Section

Source: Google image, (Visser, 2019), (Ann Marugg, ND)

According to Stefano Boeri, the project's architect, the Bosco Verticale "represents a different vision of sustainability" by bringing a new degree of biodiversity to the city. Bosco Verticale's two towers are considered a medium of a new ecology and ecosystem. Bosco Verticale's greenery is not only visually appealing but also provides a natural support system for the plants and small animals through its Trees, shrubs, and herbs, with their abundant blossoms, berries, and seeds, as well as bringing natural life to the city center of Milan. The project is a collection of plants that, in addition to being able to thrive in the artificial environment of a tall building, help to generate a diverse ecosystem (Giacomello, 2015).

The Bosco Verticale structure is completely made of concrete, with reinforced concrete columns and post-tensioned reinforced concrete beams (Giacomello, 2015).

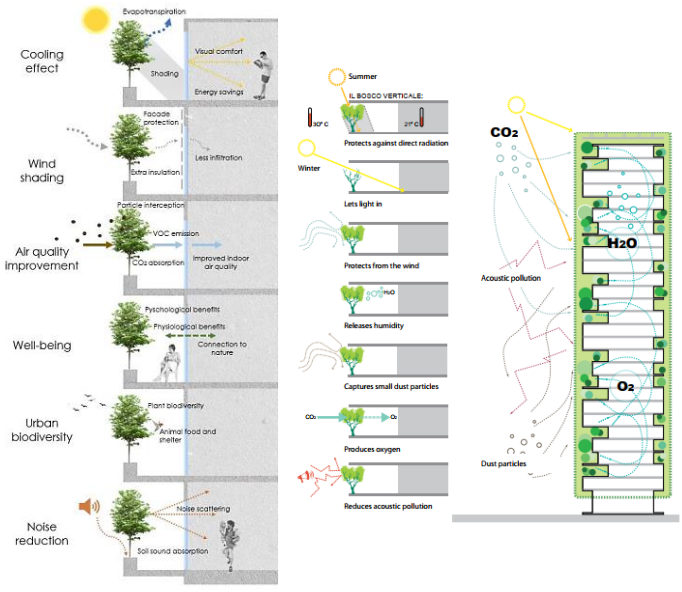

Figure 3: Bosco Verticale Two Towers, Benefits of Green Balconies

Source: Bosco Verticale floor plans and images of the two residential tower

2.5. Summery and Gaps in the Literature Review

According to the paper compiled by Matei Cocheci, the expansion of urban areas is a space-consuming process in terms of the environment which is defined by the increase in the spatial scale of a city that occurs on the outskirts of the cities. Urban expansion involves the expansion of physical structures of the urban area both horizontally and vertically which can generally be termed as urbanization. Rapid urbanization results in the degradation of the urban ecology and the urban environment. As cities expand in their spatial territory, they consume more and more land that is covered by natural wildlands and agricultural areas. To mitigate the urban ecosystem, environmental protection measures need implementation through the creation of urban forests and urban green infrastructures by which the environment can be further protected and preserved. Even though the city of Adama has different rules and regulations regarding urban green infrastructure provisions and initiatives, few measures are being taken to implement these rules. The city has been experiencing a spatial increase in its surrounding fringe with a significant increase in its population over time. The once existed environment is overtaken by the new settlement. Agricultural lands are lost, natural vegetation is cut down and barren lands are covered to make way for housing, infrastructures, and services required by the city.

Throughout the review of available literature trends of urbanization and urban expansion have been defined as well as methods such as Land Use/Land cover change mapping were addressed to look into how such mappings can assess the urban expansion of an area. Furthermore, environmental mitigation methods were observed through sustainable urban foresting methods of vertical foresting. In our country, regarding vertical foresting, there is a lack and deficiency of adequate information concerning the term and its planning, design, and implementation regarding buildings and urban land management based on the system in the realm of architecture, planning, and construction. Even though there are minor movements that might resemble the system that is related to greening, there is a lack of proper, detailed, compiled, and documented information that might help in comparing and contrasting the system from our country's point of view and outside world's view.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

This chapter consists of the overall research approach adopted, the data sources used, the data gathering techniques employed, the sampling frame, the data collection procedures, the data analysis, and the presentation approach used in planning and carrying out this research.

3.2. Description of the study area

Adama is the largest city in the Ethiopian Rift Valley, as well as other cities in the region, in terms of land coverage and population size. Fast physical expansion and frequent changes in the face of the city were linked to rapid population growth, commerce expansion, and significant rural-urban migration. Adama has seen a huge increase in the number of residents and physical area covered, making it a fantastic spot to invest and visit. It has evolved into one of the country's most rapidly changing and expanding cities ("3rd Socio-Economic Profile of Adama City", 2018).

3.2.1. Location, Size, Topography, and Climate of Adama City

The Addis Ababa-Djibouti railway line was inaugurated in 1916, resulting in the establishment of Adama city. Adama stretches astronomically from $8^0\ 27^1\ 00^{11}$ - $8^0\ 37^1\ 00^{11}$ North latitude and $39^0\ 12^1\ 00^{11}$ - $39^0\ 27^1\ 00^{11}$ East longitudes, according to data acquired from Adama City Land Management and Development Department. Adama district completely enclaves and demarcates Adama city on all four sides. The city is also located north of the well-known Awash River, which is the country's most widely used irrigation river and the source of the city's drinkable water ("3rd Socio-Economic Profile of Adama City", 2018).

According to a data source obtained (city socio-economic profile, 1996 EC/2004), the total area of the city was 13,666.5 hectares (136,665,000m^2). To the latest Master Plan, the total size of land area under the authority of the municipal administration is about 31,100 hectares which is equivalent to 311,000,000m^2 ("Disaster Risk Management Team", UIIDP, 2019).

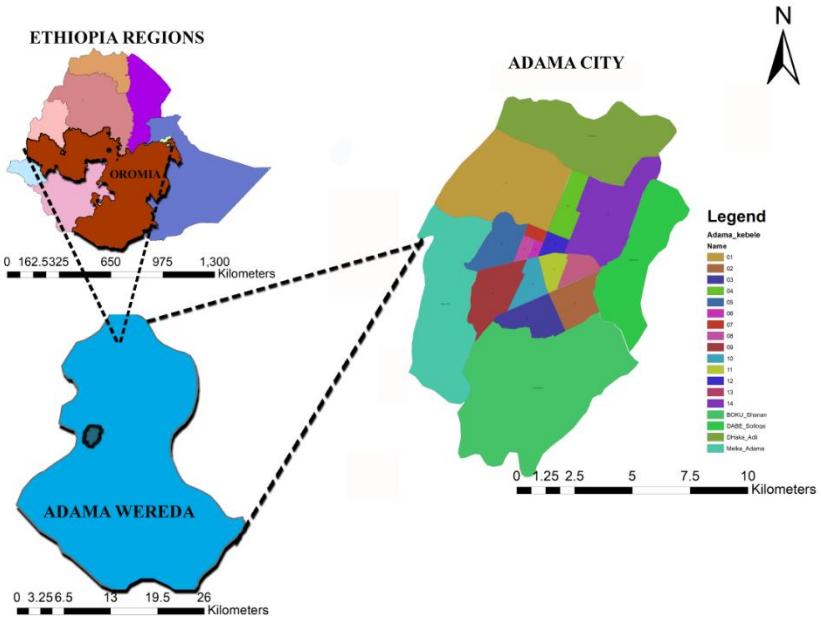

Figure 4: Location map of Adama city

Source: own computation

No	Years of Expansion	Size of the area (Ha)
1	1937 (1929 E.C)	120
2	1949 (1941 E.C)	320
3	1957/58(1949/50 E.C)	1000
4	1976/77(1968/69 E.C)	3140
5	1986 (1978 E.C)	3240
6	1991 (1983 E.C)	3420
7	2003 & 2011(1995E.C)	3,475.2
8	2004(1996E.C).	13,666.5
9	2018(2011EC)	31,100

Table 1: The area of Adama city

Source: Disaster Risk Management Team, UIIDP, 2019

The topography of the city of Adama is invariably mosaic and separated into the low-lying center and hill slopes since the city were founded on the flat and undulating fertile land that ranges from a completely low-lying center of the city to the hilly ridges overlooking the city with their unique landscape sceneries circumscribing the city, according to the city's current master plan, the city is located between 1500 and 1900 meters above sea level. The city's average elevation/altitude is 1700 meters above sea level ("4th Socio-Economic Profile of Adama City", 2019).

As Adama city lies in the Rift valley that crosses the country from north to south, Adama city falls into Kola which is a hot and dry climate throughout much of the year with sparse

rainfall in the winter and milder condition in the summer. During ten past consecutive years the maximum average and minimum average annual temperature were 29.4^{o}c and 15.15^{o}c in the year 2015/16 and 2017/18 (2007 EC and 2010 EC) respectively. Similarly, the maximum annual total rainfall and minimum annual total rainfall in the years 2008/09 and 2009/10 (2001 EC and 2002 EC) were 1106.2 mm and 492.5 mm, respectively ("4th Socio-Economic Profile of Adama City", 2019).

3.3. Research Design

A research design refers to the planning ahead of time of the methods to be utilized for gathering relevant data and the techniques to be employed in their analysis, bearing in mind the research purpose as well as the availability of personnel, time, and money. It is an arrangement of settings for data collecting and analysis that seeks to combine relevance to the study goal with the procedural economy (Kothari, 2004). The research design employed is mixed-method research which employs the use of both qualitative and quantitative analysis approaches in combination to create stronger research regarding the impacts that the surrounding green belts of the city have faced due to the city's growth.

Qualitative research examines as well as comprehends the interpretation that individuals or groups attach to a societal or human situation through developing questions and processes of data from the participant's environment that build inductively from specifics to broad themes that are generally interpreted by the researcher through words, observations, images, and maps (Creswell, 2009). The research acquired data from sources through the self-administered questionnaires, in-depth interviews, and field surveys by identifying the essence and understanding of the lived experience described by participants, in the case of this research being the impacts that the surrounding green belt areas of the city of Adama has faced due to its physical expansion over the years.

Quantitative research investigates the relationship between variables to test objective ideas by which these variables can then be monitored using instruments of numbered data that are examined using statistical methods through mathematical computations (Creswell, 2009). The research adopted a statistical study for a better inference about the population based on the sample result. This is because the study needs the collection of statistical (numerical) data for the quantitative approach and the qualitative method applied to describe the existing conditions of the physical expansion of Adama city from the participants.

3.4. Types and Sources of Data

Primary and secondary data are the two categories of data that are used in this research to attain the listed objectives. Primary data can be obtained through observation, direct communication with respondents in various forms, or personal interviews in sample surveys or census surveys. Secondary data refers to readily available information, i.e., data that has been gathered and assessed by others in the past (Kothari, 2004).

The primary data in this research was acquired from the researcher's direct involvement in the form of a thorough observation through a field survey, a self-administered questionnaire, and an in-depth interview of key informants. Through the primary data, the researcher was able to achieve information regarding the physical expansion of Adama city and its impacts that may have been faced by the surrounding green belts of the city (Agricultural/farmland, Natural vegetative land, and bare land) from involved participants/respondents and informants.

The secondary data was acquired through desk reviews done on articles, books, different organizations' documents, reports, journals, research, and standard literature. Satellite images, population data, aerial photographs, and topographic maps of Adama city were also used as significant data sources for the research. The researcher was able to quantify the land use and land cover change that the city experienced over the past 20 years in 7-year intervals to further acquire information concerning the change in scenery of the city's land cover through time.

Both primary and secondary data were also collected from areas of government bodies including the Adama municipality office, Adama land administration, and Adama central statistics agency on data that is relevant for the research.

3.5. Data Collection Methods

As mentioned above the data obtained for the research were collected from self-administered questionnaires with the aid of data collectors, in-depth interviews involving certain informants, and field surveys concerning the primary data requirements, while desk review through available documented materials was done concerning the secondary data requirements. Both the primary data and secondary data collection methods were also used to attain data on the physical expansion of Adama city and the land cover changes that the city faced over the past 20 years through satellite image classification and processing respectively.

3.5.1. Self-Administered Questionnaires

The questionnaires were prepared and supplied in such a way that it would be feasible for the local community's understanding, primarily being prepared in English and then translated to Amharic and Affan Oromo. The questionnaires were supplied to the different respondents in the form of both open-ended and close-ended question formats by the direct administration of the different data collectors who explained the questions to the participants/respondents for their better understanding. The general purpose of the questionnaires was for understanding the lived experiences of participants/respondents concerning the changes in the physical setting of the city and the effects it brought about on the green belts surrounding the city.

3.5.2. In-Depth Interviews

The in-depth interview was a direct engagement and a face-to-face interaction between the researcher and different informants concerning the key aspects of the Adama city's expansion especially topographical or physical expansion over time and its outcomes. The researcher describes these informants as officials from the Adama municipality office and the Adama land administration office.

3.5.3. Field Survey

The field survey was conducted by the researcher in the form of site observation of the surrounding environment of Adama city. The researchers observed the different land uses existent in the surrounding area which the research dubbed green belts (i.e., Agricultural/farmland, vegetative land, and bare land) to further compute the impact that occurred on those land uses by the physical expansion of the city. The field survey was also beneficial in distributing the questionnaires to different participants and in conducting the interviews.

3.5.4. Desk Review

The desk review was conducted to acquire documented accounts in the form of literature concerning trends of expansion and its impacts around the world and on the city of Adama. The documents were used to explain the city's physical expansion trend. Different reviews were also used to understand the impacts of a city's growth on the environment to better understand the impacts faced by the surrounding greenbelt of the city of Adama. There were also similar studies conducted on the vertical foresting system, its current experience, and trends in the world to put forward this concept as a possible mitigating solution by taking

into consideration the current situation of the country. Different secondary data were used as inputs for further analysis methods.

3.5.4.1. Population Distribution of Adama City

The city's average annual population growth rate is still high, at about 4.8 percent, which is higher than the national and Oromia urban population growth rates, which are now at 3.8 percent and 4.6 percent per annum, respectively. According to the country's third population and housing census, the city's population nearly doubled between 1994 and 2007. According to projected demographic figures from 2010 EC, the population of the shining city of Adama was 413,236 people, with 206,153 men and 207,083 women, indicating the city's strong urban growth ("3rdSocio-Economic Profile of Adama City", 2018). It is organized administratively into six higher administrative units known as "Kutaa Magaalaa" and 18 smaller administrative units known as "Gandas." ("Disaster Risk Management Team", UIIDP, 2019).

City	Year	Male	Female	Total
Adama	2001	117,303	119,963	237,266
	2002	139,309	141,969	281,279
	2003	146,108	148,898	295,006
	2004	152,654	155,569	308,224
	2005	160,502	163,567	324,068
	2006	168,060	171,269	339,329
	2007	176,487	179,857	356,344
	2008	185,107	188,554	373,661
	2009	193,992	197,605	391,597
	2010	206,153	207,083	413,236

Table 2: The Projected Population Size of Adama from the Year 2001–2010 E.C

Source: Socio-economic profile of Adama city, 2019

3.5.4.2. Expansion Areas of Adama City

According to Adama city land administration, Adama has four main expansion areas which include Dhak_ Adi with a total area of about 1701.414 hectares in the north direction, Malka_Adama which is 1837.772 hectares, Boku_Shanan 3904.682 hectares of land in the area, Dabe_Solloqe which is 1229.566 hectares in area, located in Northeast, Southwest, South, East of Adama city center respectively

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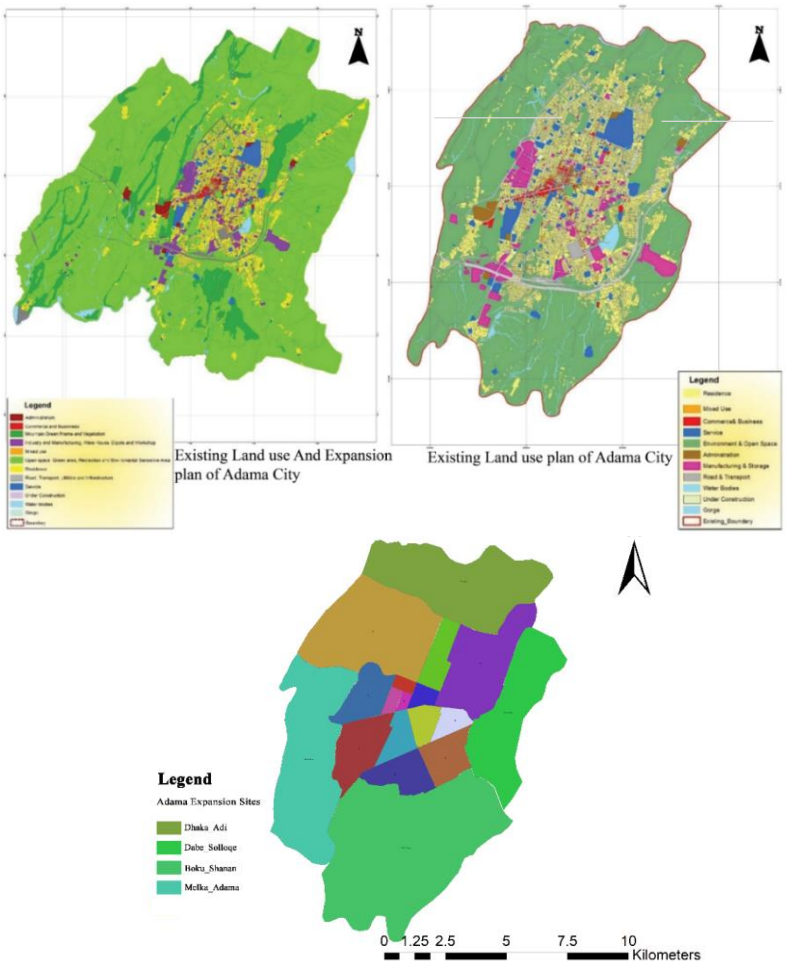


Figure 5: The expansion sites of Adama city

Source: Researcher's own computation

3.5.5. Satellite Imagery

For studying, the urban expansion of the city of Adama a cloud-free image of the city was acquired from the website with Landsat imagery of the years (2000, 2007, 2014, and 2021) from the United States Geological Survey (USGS) Earth Explorer website and spatially referenced in the Universal Transverse Mercator (UTM) projection with datum World Geodetic System (WGS) 1984 UTM zone 37N by which the data were used to produce the study areas land use/ land cover maps and urban expansion changes.

3.5.5.1. Land use/land cover mapping

By considering the impacts of Adama city growth on the greenbelt, LU/LC maps of the study area were prepared over the past 20 years by the time interval of 7 years (2000, 2007, 2014, 2021) GC.

No	Land use/land cover classes	Description
1	Urban built-up area	Urban Areas that are occupied by basic infrastructure include Residential, Industrial, Commercial units, Road networks, Transportation, Mixed urban, and other facilities.
2	Agricultural land	Areas that are used for crop cultivation, irrigated lands, farming and
3	Natural Vegetated areas	Natural forests, Woodland shrubs, and Natural grasslands
4	Bare land	Non-vegetated areas, sands, rocky areas, and all vacant spaces

Table 3: Land use/land cover classes and description

Source: Researcher's own computation

3.5.5.2. Data Collection

This study requires data acquired at different periods in the same space. In the light of this Landsat imagery was downloaded starting from 2000 up to 2021 within the 7-year interval during the accusation of Landsat time serious data quality criteria like single data run, phenology, and collection level are considered to minimize the error during classification. Because of phenology, vegetation has a wide range of reflectance, making land cover change monitoring difficult. Ideally, multi-temporal images for change monitoring should be from the same season considering for this study all images were acquired during the driest season, particularly in December

In this study Landsat collection 1 level, 1 data used. L1TP products have the highest radiometric and geometric accuracy to avoid SLC off error in Landsat 7 after May 2003 the study profited from the use of Landsat-5TM image for 2007 as this avoided the effect of those missing data in 7 ETM+ for this year due to SLC (Scan Line Corrector) failure from 2003 till 2013 that would result in data losses at about 20%.

No	Landsat scene ID	Scene_Center_Time In GMT	Cloud coverage %
1	LE07_L1TP_168054_20001205_20170208_01_T1	"07:30:42.0892444Z"	0.00
2	LT05_L1TP_168054_20071225_20161231_01_T1	"07:30:43.8774328Z"	0.00
3	LC08_L1TP_168054_20141220_20170416_01_T1	"07:40:31.3122160Z"	0.76
4	LC08_L1TP_168054_20211223_20211230_01_T1	"07:40:42.1459280Z"	1.19

Table 4: Landsat scene ID

Source: Analysis of Satellite images, 2022GC

3.5.5.3. Pre-processing

Sampling of class

The sample take for each of the four consecutive years of (2000,2007,2014, and 2021) is as follows.

	Classes	Sample size (2000)	Sample size (2007)	Sample size (2014)	Sample size (2021)
1	Urban land	750	948	1200	1576
2	Agricultural land	2470	2089	2200	953
3	Vegetation	1432	1390	835	1500
4	Bare land	590	643	802	1000

Table 5: Sample Size Selection

Source: Analysis of Satellite images, 2022GC

The Sample source is independent and different from those used in for the training and are collected based on knowledge of the study area and from other published literatures.

Radiometric calibration

Radiometric correction of remote sensing images is required to improve the quality of image pixel values and provide a measurable physical unit of each pixel and determine the true reflectance value of the earth's surface. A radiometric correction was performed in ENVI software using a radiometric calibration tool and all the images were converted to radiance and then finally to the correct surface reflectance.

ENVI have two methods for calculating confusion matrix (Agreement between the classified image and true source) thus area ground truth image and ground truth region of interest, for this study “classified ground truth image as true source” is not available so the only possible side is using ground truth region of interest. In this method the user provides ROI that use as true source ENVI selects sample point from this input ROI then calculate confusion matrix.

Atmospheric correction

All of the images are corrected for the atmospheric condition through ENVI through FLAASH atmospheric correction using input from its metadata text file (MTL.txt) and scale from 0 up to 1using the band math tool in ENVI.

Layer stacking

Landsat satellite provides multispectral imagery: an image produced by a sensor that measures the reflected energy within several specific sections/bands separately each band has unique functions and characteristics. These sections/bands have to be combined/stacked as one to use the image in a typical manner and to produce a single multi-band image. ENVI layer stacking tool used for stacking individual bands as one multispectral image.

Re project and Subset/resizing of the study area

Each Image reference system is converted to Adindan to make it similar to the ancillary data. The study area is Adama city previous structural plan of the city is used as a boundary to subset the study area section from the imagery.

3.5.5.4. Image classification

For this study Support, the Vector Machine classification (SVM) algorithm is selected in the view of the SVM algorithm doesn't affect training sample size and their distribution which is the most important in supervised image classification. Moreover, it's important for the problem of mixed pixel problems in the urban area. It is a supervised classification method derived from statistical learning theory that often yields good classification results from complex and noisy data.

Training data

Good quality training data are needed to 'teach' the classifying software to recognize similar patterns in the imagery. These represent only a small sample of the entire image/region to be classified

Evaluating Training data

The collected signature should have to be tested before being used for the classification purpose of this study total sum of a pixel in each ROI (class) and ROI separability is selected. Based on the rule of thumb the number of pixels in each training class at least should not be less than 100 times the number of spectral bands used (Dr. Michael Govorov, Malaspina University-College, with attribution to IDRISI) And ROI separability was determined by using the "Jeffries-Matusita and Transformed Divergence separability" measures, and a separability index was computed between each pair of training samples the values of ROI separability range from 0 to 2, and the value greater than 1.8 is often considered to be a high-quality training sample (Yang et al, 2017).

Pixel in (ROI)	2000	2007	2014	2021
Urban land	1019	2658	3072	4301
Agricultural Land	7894	10329	5859	6831
Bare land	5606	7876	3389	4397
Vegetation	2143	3669	1009	2097

Table 6: Pixel (ROI)

Source: Analysis of Satellite images, 2022GC

Training (ROI) Separability	Maximum	Minimum
2000	1.98947176	1.81615592
2007	1.89926760	1.82567869
2014	1.94227818	1.85737331
2021	1.92987078	1.87116334

Table 7**:** Training (ROI) Separability

Source: Analysis of Satellite images, 2022GC

3.5.5.5. Accuracy Assessment

Accuracy assessment is a process used to validate the accuracy of image classification by comparing the classified image with reference data. An accuracy assessment tool to select a set of randomly selected pixels whose true values were well known (Njiru, 2016). The major goal of accuracy assessment is to quantitatively evaluate the sampled pixels to find out how effectively they are used in the right Land Cove classes (Rwanga, S.S & Ndambuki, J.M, 2017).

Confusion Matrix can be mentioned as one of the systems employed in the assessment of Accuracy regarding the classified image which is a system that provides both statistical and analytical ways of explaining the accuracy of the classification. This method can be used in quality measures such as user accuracy, producer accuracy, overall accuracy, and Kappa analysis. Reference data are acquired from field surveys, aerial imageries, and photographs, and high-resolution images from Google earth are used for accuracy assessment (Yimam, 2017).

For the purpose of this research the land use land cover change analysis source for accuracy assessment point is User provides ROI (region of interest).

3.5.5.6. Overall Accuracy

This is calculated by dividing the total number of correctly classified pixels or the diagonal value (Xii) by the total number of pixels in the matrix (N).

$$\textbf{Overall Accuracy} = \sum xii/N$$

The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data is at least 85 percent (Anderson,1983) by which A minimum level of accuracy of about 85 to 90 percent or better should be approached in that interpretation of the imagery being used (Anderson,1971).

3.5.5.7. Producer Accuracy

The conditional chance of accurately mapping a place assuming that it is the true class is referred to as producer accuracy (Stehman et al, 2003). The producer of the classification is interested in how well a certain area can be classified and so producer accuracy is the total number of correct samples in a category (Number correctly identified in a given map class) is divided by the total number of samples of that category (Number claimed to be in that map class) as derived from the reference data (i.e., the column total) (Congalton, 2001).

3.5.5.8. User Accuracy

The conditional chance of accurately categorizing a location assuming that it has been mapped as the class is referred to as user accuracy (Stehman et al, 2003). The chance that a sample classified on the map/image represents that category on the ground, and hence the overall number of correct samples in a category, is determined by the user's accuracy or dependability or reliability (Number correctly identified in reference plots of a given class) is divided by the total number of samples that were classified in that category (Number actually in that reference class), then this result is a measure of commission error (Congalton, 2001).

3.5.5.9. Kappa Analysis

Kappa coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated. The kappa was a discrete multivariate accuracy measurement tool. (Yimam, 2017).

The Kappa coefficient (K) is calculated by using the following adopted formula given by Congalton, 1991

$$K = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{ii} \times X_{i+1})}{N2 - \sum_{i=1}^{r} (X_{i+} \times X_{i+1})}$$

Where: r = is the number of rows in the matrix;

Xii = is the number of observations in rows i and column i (along the major diagonal);

Xi+ = the marginal total of row i (right of the matrix);

Xi+1 are the marginal totals of column i (bottom of the matrix);

N is the total number of observations (Berisa, 2012).

3.6. Sampling Methods and Technique

The Sampling technique is a process of selecting a sample from a given population. For this research, the researcher used a probability sampling design technique by which both simple random sampling and stratified sampling were used in combination. It is important to use random and unbiased sampling methods that represent the population to make inferential statistics by obtaining a representative sample through stratification of a population into subpopulations or strata to select samples from each stratum (Kothari, 2004). As it is better to reduce the uncertainty and errors in the inferential statistics by employing probability sampling methods regarding the quantitative data.

3.6.1. Sample Size

According to the 2010 EC national census report, Adama city has a population of 413,236 people ("4th Socio-Economic Profile of Adama City", 2019). Because it delivers the proportional probability for all the sampled populations, a combination of simple random and stratified sampling techniques was used. The sample size was determined using a formula developed by Yamane (1967GC). The total population size was sampled through probability sampling technique using random sampling and the sample size was dependent on the ability to acquire desired reliability.

$$n = N / (1 + Ne^2)$$

Where; n= sample size, N = population size (413,236), and e = Margin of error (MoE) which is 0.05 for 95% confident level. The total sample is 400.

The studied population was stratified into several strata and sample items were selected from each stratum by using a simple random sampling technique. The stratified sampling was more appropriate, which further facilitates the comparison strategy. As a result, the total number of people was stratified first, followed by a simple random selection.

The next table represents the samples per each kebele using the method of proportional allocation defined by the formula:

$$ni = (N_i / N)\, n$$

Where ni= sample size per each kebele (computing to proportional allocation), Ni= per kebele total number of populations, N= total number of populations, and n= total sample.

Kebele	Total number of residents (population)	Sample size
01 (Goro)	32,083	31
02 (Migira)	22,980	22
03 (Gara lugo)	33,474	32
04 (Tedecha arara)	34,133	33
05 (Dagaga)	32,234	31
06 (Gurmu)	12,214	12
07 (Badhatu)	19,678	19
08 (Oda)	18,591	18
09 (Errecha)	37,098	36
10 (Biqa)	30,079	29
11 (Barecha)	31,593	31
12 (Gada)	18,158	18
13 (chafe)	18,448	18
14 (Angatu)	35,152	34
Boku Shenan	10,850	10
Dhaka Adi	5,053	5
Dhabe Solloque	14,524	14
Melka Adama	6,894	7
Total	413,236	400

Table 8: Sample size of the population

Source: Researcher’s own computation

3.6.2. Sample Design

The sampling design employed in the study for the respondents is inventoried in the 18 kebeles of Adama city. The primary data acquired from self-administered questionnaires was attained from the strata of the 18 kebeles of the city. The in-depth interview of key informants of officials was selected for the in-depth interview based on the informant's skills, or position within a society and the city that allows them to provide better insight into the conditions and situation concerning their position. Informants and officials were selected from Adama city's municipality office and the Land administration agency of the city in the form that (Creswell 2009) recommended which is between 5-25.

3.7. Data Processing and Analyzing Method

The researcher was involved in using various materials and instruments to analyze both primary and secondary data. To analyze primary data involving field surveys, the researcher used video, voice, and camera recording phones, USB flash drives, and note pads to record pieces of information and receive electronic documents that served as secondary sources of data. For the analysis of secondary data, the researcher used software that included, **SPSS** for the analysis of collected data; **MS Excel 2016**, to perform different statically calculations; **Global mapper 20 (64 bit)**; **ArcGIS 10.3** for the extraction of satellite imageries for the identification of the city's features, to create study area shape-file, identify path and row of the study area, data analysis, management, geo-referencing, the study area delineation, and clipping and make a layout for final mapping; **ERDAS Imagine** to image pre-processing, supervised classification of land classes and accuracy assessment of the classification; **Revit architecture 2020** to design of the proposed vertical forest expansion site; **Adobe Illustrator cc 2019** to integration and incorporation of the above information; **Lumion** to present rendered images of the final design; and **MS Word** for the presentation of the final report.

The analyzed data were presented by using tables, figures, plans, and maps, accompanied by textual discussions. The tables, figures, plans, and maps were constructed and listed in such a way that they can clarify significant relationships and become self-explanatory. After doing (conducting) the study as per the methods identified earlier, the analysis made on the sample taken was interpreted for the population, and the conclusion was deduced. The results after interpretation were also validated by using past data.

3.8. Ethical Consideration

Officially letters were provided by the institute of Adama Science and Technology University to the different organizations for their willingness to share information required by the researcher. These letters respectfully asked for the compliance of Adama city municipality and other organizations that the researcher might deem important for the gathering of information. The researcher also kept in mind the confidentiality of different subjects involved in the research process in which no personal information was portrayed in any form of record.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The result and discussion of a study is the main chapter that aims to fulfill the objective set out by the researcher. In this research, the result and discussion chapter are concerned with providing major findings regarding the impacts faced by the surrounding green belt of Adama city due to the city's rapid growth i.e., Physical expansion. The analysis and results of the research are reported in this chapter to draw the inference of the study both qualitatively and quantitatively. Different data gathering techniques were used to analyze and interpret the data collected. Citizens and informants with officials from municipality officials of Adama city were provided with questionnaires and in-depth interviews respectively, while different documents were reviewed to provide further insight and support for the acquired information, and a field survey was conducted for a better understanding of the situation. For further information regarding the study Land Use/ Land Cover change analysis was conducted on the study area and the physical expansion of the city of Adama was thoroughly assessed and analyzed.

4.1. Characteristics of Respondent's Questionnaire Results

4.1.1. Demographic Characteristics of the Respondents

4.1.1.1. Sex of Respondents

From the result obtained the dominant sex from the respondents were Males. The Males held about (N=58.3%), while the Females held about (N=42%) of the total respondents in question.

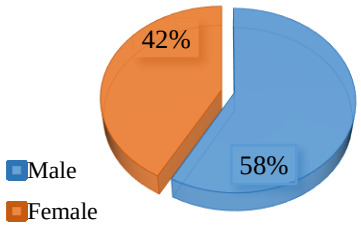


Figure 6: Sex of the Respondents

Source: Research Survey data

4.1.1.2. Age of Respondents

According to the Age category, respondents' age group ranged from 15 years of age to 60 years and above. The majority of respondents were between the age of 45 and 49 having a percentage of (N=17.5%) followed by the age groups of 40-44 having a percentage of (N=15.5%). The least number of respondents were aged 29 years and below.

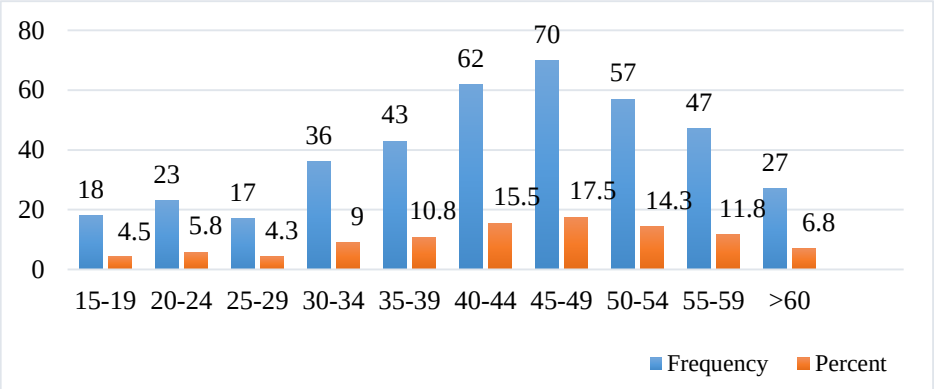


Figure 7: Age of the Respondents

Source: Research Survey data

4.1.1.3. Educational Qualification of Respondents

As shown in the chart the majority of the respondent's educational qualifications ranged between diploma level and high school level of education with a percentage of (N=24.2%) and (N=20%) respectively. Followed by uneducated respondents, which held a percentage of (N=19.8%). The least dominancy was held by those with Masters and Ph.D. levels of education with a percentage of (N=4.2%) and (N=1.2%) respectively. This implies respondents of varied educational levels were considered in the study which showed that unbiased information was gathered from both the educated and uneducated sectors of society.

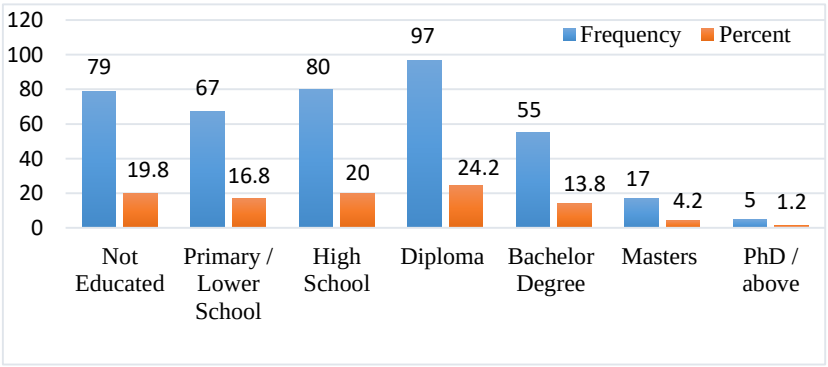


Figure 8: Education of the Respondents

Source: Research Survey data, 2021

4.1.1.4. Years of Residency of Respondents

Regarding the number of years each respondent had lived in the city of Adama, the respondents who lived about 20 years and above were about 35.5% while those who lived between 14-19 years were about (N=27.2%). The respondents who lived a year or less were the least holding about (N=8.8%) of the total respondents. About (N=10.5%) of the respondents were those who lived between 2-7 years. This shows that the majority of

respondents lived 14 years and above that means the respondents had better insight into the physical change that the city experienced in due time.

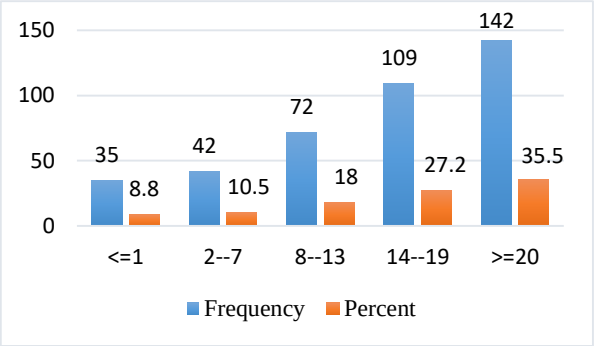


Figure 9: Residency of the Respondents

Source: Research Survey data

4.1.2. General Perception of Respondents

4.1.2.1. Growth of Adama city from Respondents' Insight

From the result obtained from the total respondents those who favored the growth of the city of Adama were about (N=98.2%), while those who argued against the growth occupied about (N=1.8%) out of the total number of respondents.

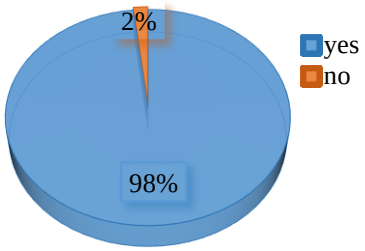


Figure 10: Growth of the city according to respondents

Source: Research Survey data

4.1.2.2. Reasons for Adama City Growth from Respondents' Insight

Among the open-ended questions provided for the respondents on their insight towards Adama city growth, about (N=67%) of them replied that the city has grown economically (through its creation of different hotels, job opportunities, different infrastructures such as shops of clothes, and electronics and so on), socially (as different people come from different parts of the country), culturally (because of the existence of people of different ethnicity and culture from the nation's nationalities and peoples of Ethiopia) and geographically (because there are areas covered with housings that were empty before). About (N=21.5%) of the respondents believed that Adama has grown in its economy (because of infrastructures like shopping centers, technological advancements such as Wi-Fi and network accesses and so on), society (because there are people of different culture coming from different areas of

Ethiopia to live and work in the city), politics (through its ability to manage and administer its city as a capital of the Oromia regions, existence of well-known conference hall known as Aba Gada conference hall for holding different meetings of governmental and non-governmental issues) and geography while the remaining percentage of (N=9%) of respondents favored that the city has only grown in its economy (as it has different international hotels, shops, and access to technologies like availability of latest phones and accessories and Wi-Fi, the city hosting different meetings of government, productivity of people that open pensions and hotels because of economy got by the people coming very often for meeting purposes and so on) and geography (because of people buy land commonly known as "Chereka Bet/informal settlement" in the local language, displaced people come and government gives land and houses for them in originally empty areas, government builds houses for teacher communities and supply it with pay for the teachers of different school in the city and so on). Generally, they tried to explain their view in such a way that they believed a city is growing when it exhibits different changes that weren't there before.

4.1.2.3. Physical expansion of Adama city from Respondents Insight

Almost a total of the respondents with a percentage of (N=83%) were in favor of the physical expansion of the city of Adama as the respondents believed the area of the city had expanded over time.

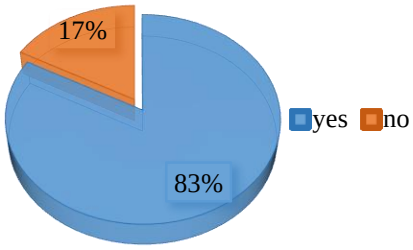


Figure 11: Physical expansion of the city according to respondents

Source: Research Survey data

4.1.2.4. Reasons for Adama City Physical expansion from Respondents' Insight

As shown from the chart below the majority of respondents (N=30.1%) were in favor of the fact that housing/residential needs were the main factors for the physical expansion of the city of Adama. Respondents were also quick to answer that road construction and transportation were the accompanying factors for the expansion of the city, which held (N=22.9%). The respondents also pointed out that Commercial and business; and Market and investments also added to the exhibited physical change of the city with a percentage of

about (N=19.3%) and (N=16.3%) respectively. More than a quarter of the respondents chose industry creation as another factor for the expansion.

For the open-ended questionnaire that inquired respondents to better elaborate on their responses, those who replied in favor of housing and residential needs said that they are observing the construction of more and more housing on peripheries of the city, with the increasing number of informal settlers building their houses and an increasing number of different displaced persons are given land for their livelihood by the administration of the city. Respondents also replied that roads and transportation construction is increasing following the housing provided and as trade routes to neighboring cities both around and through the city. Commercial and business; and Market investments have also increased due to the increasing population in the city. Different private and government bodies are also engaged construction of different small and large industries for the development of the city.

This implies that Adama city is perceived to have physically expanded at an alarming rate mainly due to the rising population of the city which has in turn accelerated the need for the construction of infrastructures.

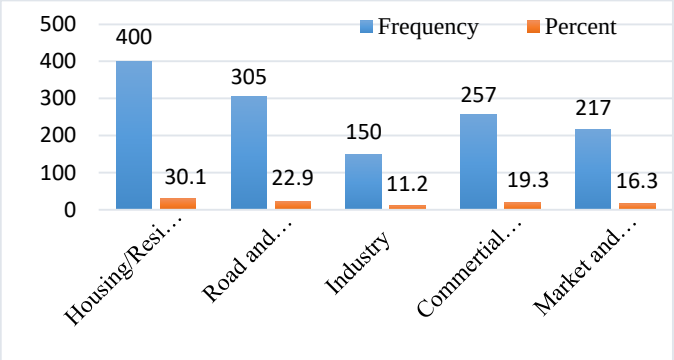


Figure 12: Reasons for physical expansion according to the respondents

Source: Research Survey data

4.1.2.5. Impacts of the Physical Expansion of the City on the Surrounding Green Belt Area

Out of the total respondents questioned on the impacts brought by the physical expansion on the surrounding green belt of the city, about (N=81%) of them responded yes to the change that occurred physically has brought about negative impacts on the surrounding green belt areas of the city, while the remaining (N=19%) of respondents believed that no significant

change has occurred on the surrounding green belt that can be considered to bring negative impacts on it, even though the city has shown physical expansion.

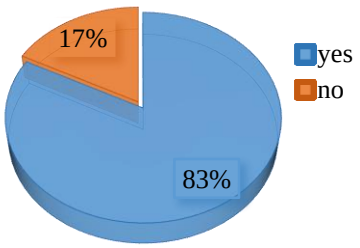


Figure 13: Impacts on surrounding green belt

Source: Research Survey data

4.1.2.6. Areas of the Surrounding Greenbelt Negatively Affected

Bare land/open area with (N=36.1%) and Agricultural land/farm land with (N=34.9%) were mentioned as the dominant areas that exhibited the negative impacts of the city's physical expansion. The respondents replied loss of existing agricultural land, the loss of once bare lands, and their repurposed use for other features such as infrastructures can be mentioned as the main reasons for the decline faced by both agricultural and bare land. Respondents that accounted for (N=28.9%) also described that the natural vegetative land is also affected dearly because of the expansion as deforestation has been occurring time after time which has shown scarcity of native natural vegetation and the accompanying loss of biodiversity on both plant and animal lives.

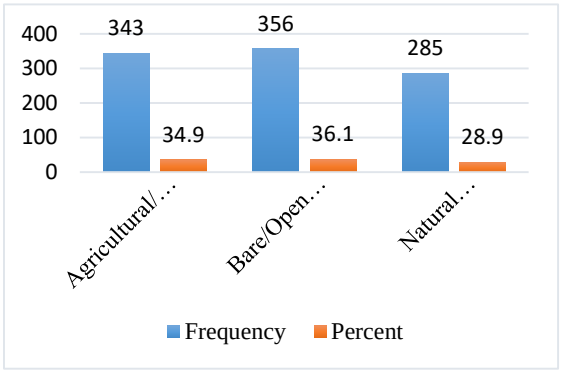


Figure 14: Green belts negatively affected according to the respondents

Source: Research Survey data

The above information implies that agricultural land and bare/open land have been significantly altered because of the rising land consumption of the population of Adama. Due to the increase in the number of citizens living in the city over time and as a result land is being consumed and changed to fulfill the needs of those citizens.

4.1.3. Perception of Respondent towards Vertical Foresting

4.1.3.1. Meaning of Vertical Foresting

Among the open-ended questions provided to the respondents, respondents were asked to describe their knowledge of vertical foresting before they were addressed by the researchers through this questionnaire. The majority of respondents which accounted for (N=56.5%) had no knowledge and awareness of the concept of vertical foresting and had no understanding of the term as a whole. About (N=38%) of respondents believed the term was concerned with forests that had trees and different kinds of plants located inside the city relating it mainly to the provision of greenery. The remaining percentage of respondents with about (N=5.5%) had some sort of understanding of the concept by which they described it as planting plants on different materials such as pots and placing them on their house's balconies, corridors, and lobbies as well as planting trees in their houses and their surroundings.

This implies that different sustainability approaches such as new and innovative green infrastructure provisions methods are not clearly understood by the respondents. This shows that there is a significant lack of awareness regarding sustainability and how to achieve it.

4.1.3.2. Vertical Foresting as Mitigating Action

After the respondents were approached by the researcher and given a thorough explanation of the concept matter, they were inquired to integrate their earlier knowledge into their newfound awareness of vertical foresting, to provide answers to the question provided that is, whether or not they believed that vertical foresting can be a mitigation action towards the impacts faced by surrounding areas of the green belt for the city of Adama. The majority of the respondents (N=68%) were those who understood the concept was in favor of supporting the natural environment, they were keen to understand that a building could be integrated with the environment and the city because they believed this concept could show that people can return the already diminished natural environment by living with it in their homes. The remaining (N=32%) respondents had great doubt about the concept's relevance even though the researcher had already explained the concept and its benefit and advantages.

This implies that if there is a proper awareness created in the respondent regarding environmental protection and sustainability concepts, the respondent is eager to act on the measures to be taken to accomplish them. We can also conclude that the respondent is highly interested in protecting and preserving the environment as much as they can if there is the

right venture opened for this purpose. In the case of this research, respondents were quick to understand and provide support for the concept of vertical foresting as a sustainable approach toward environmental benefit.

4.2. In-Depth Interview

An in-depth interview is an interview method conducted in a thorough and detailed manner between an interviewer and interviewee. In the case of this research, in-depth interview was provided for officials and informants in the governmental sector from city administration offices such as the Adama municipality office and Adama land administration offices. From the interview conducted between the researcher and the official key aspects of the city's expansion and its outcomes. The researcher, therefore, had organized 5 main and important questions for the interview. At the end of the interview, the researcher provided a general summary and relevant conclusion on the information acquired from the interview. The following are the major issues mentioned in the interview.

1. The first interview question was concerned with the physical expansion of the city and its impact on the surrounding environment of the city particularly on the existed green belt.
2. The second question inquires response on what solutions the city administration is working on to mitigate the physical expansion of the city.
3. The third question is concerned with what solutions the city administration is working on to mitigate the affected parts of the environment specifically the existed green belt surrounding the city.
4. The fourth question inquires if the city has provided certain rules and regulations regarding environmental protection, preservation, and implementation strategies in collaboration with sustainability issues for the city.
5. The fifth question inquires officials to explain their views and experience of the city regarding the sustainability attaining approach through vertical foresting.

The researcher provided the response of the officials in a combined and integrated manner to better elaborate and shed light on the questions provided.

Adama is a city that is experiencing fast physical growth and expansion due to its extending regional and national level development of infrastructures that pass through the city. Because of the natural population increase and its rural-urban migration of citizens in search of jobs, the city is extending further. They also indicated that the urban land expansion has been

recognized by the city administration and is supported by the administration through based assessment and preparation of study required and recognized and therefore has provided 5 main expansion sites for the future expansion development of the city; Namely Dhaka Adi, Ganda Goro, Malka Adama, Boku Shenan, and Dhabe Solloque.

The officials also explained that human congestion and population increase have been rising at an alarming rate over the years in the city of Adama. As a result of this increase, the urban environment is faced with pollution. The provision of large recreational parks in identified areas of green infrastructures on the city's structural plan is focused on by the city administration as a mitigation action. This is achieved through the rule of urban land allocation put forward by the National Urban Greenery Development Strategy, which states that 30%, 40%, and 30% of the land is given to greenery, construction, and roads respectively for better development and management of green infrastructures to create favorable environment situation for inhabitants as the city of Adama is a city of the conference, investment, recreation, culture, and residence.

The officials pointed out that different researches have been and are being conducted comprehensively by many researchers on issues of urban greenery and its status through the sponsorship of the city's administration as urban greenery issues have become major municipal activities in Adama city. They implied that they have been working on implementing 14 of the components from the 17 urban UGI components identified in the Federal MUDC Manuscripts which include; Recreational Parks, Urban Agriculture, Green Roofs and Living Walls, Urban Forests and Wet Lands, Open Space in administrative and commercial compounds, residential areas and schools, Urban Seeding Nursery and others. In addition to this Adama, the city has intended to achieve greenery developments in 10 years' plans. The city administration is working to support this plan through urban greenery manuscripts, strategies, and standards, Adama thinking of creating awareness for leaders of the city, sub-cities and "Genda", stockholders, MSEs, and other community representatives. In addition to this, it is involved in projects i.e., the four urban green frames (Oboo Park, Migra, Sire Aba Bune, and Boku) provided in the city master plan were planted, protected, and managed.

Among the 10 years plan of greenery targets some of them include; To respect greenery sites on the master plan with allocated land being titled indeed so that abuse of the site by different bodies of offices will be controlled; To develop greenery areas with green infrastructure

standards; Development of neighborhood green spaces, protecting and upgrading mountainous green frames for example for kebeles of Migira, Boku and Sire Aba Bune for purpose of creating of parks; Nursery operation for raising different species of plant seedlings; protecting pre-urban forests from destructive factors; Establishing greenhouse in the existing municipal nursery and so on.

Since the design of the 10 years plan of greenery target, Adama city has shown initiation and movements towards achieving the plan, for instance, the Dembela Recreational Park development in 53 hectares can be mentioned as one of them as it is the first site for a typical park. The project is undertaken by Adama city administration staff and ASTU by which surveying work, land use plan, design, and biological have already been done. The second site is the Wetland of Adama, Migira site which is fenced with wires and protected by guards. The third site in movement is the Boku hot spring, which is protected by municipality guards

Adama city follows rules and regulations from the constitution of FDRE from Article (43) and Article (44) regarding sustainable development and Article (92) regarding environmental rights. In addition to this, the city also implements the rule regarding urban land allocation from the National Urban Greenery Development Strategy (NUGDS).

The officials believed that the term vertical foresting is a new concept that is not commonly explored both at our city and country level. They implied that the term is observed mostly in developed countries rather than developing ones such as ours. Realizing that sustainability can be achieved through different greening strategies, officials were keen to point out that the term could be given attention and consideration through more relevant methods in our countries and cities. They believed that a term could have more acceptability towards society if it shows its relation with society and if it is approached more easily and understandably. Such can be achieved by starting small and going bigger in implementation strategies of the concept that considers our country's standards and availability of resources required to do so. By showing that planting in different planting materials such as pots and placing them on areas of balconies, lobbies, and corridors; By creating nurseries in homes and residences to serve as courtyards and buffers surrounding their homes; By providing plants such as ivy plants that are evergreen and climbing on the walls of buildings; and Integrating greening systems such as green roofing for buildings that are in the planning and design stages for future developments we can be able to make vertical foresting more approachable and obtainable.

There is a habit of planting different plants and fruits in the city of Adama by the society which shows that if the proper action is taken to make the concept clear to society it will not be hard to create strategies and systems for its proper implementation.

4.3. Land Use/Land Cover Change Detection of Adama City

4.3.1. Land Use/Land Cover in 2000 GC

In the year 2000GC, the data obtained from the land use/land cover change detection showed that agricultural land held the dominant area coverage with a staggering total area of 9518.13Ha (71.15%) followed by the area covered by bare land which held a total area of about 1898.37Ha (14.19%). The natural vegetative area at that time was about 961.11Ha (7.18%) with minimal area coverage. Urban land held an area coverage of about 999.45Ha (7.47%). The land use/land cover change detection in the following years of the study area and study time intervals were based on the above area coverage.

Class Name (2000)	Area in Hectares	Area in Percent
Agricultural Land	9518.13	71.15
Vegetation	961.11	7.18
Bare Land	1898.37	14.19
Urban land	999.45	7.47
Total	13377.1	100

Table 9: Area and percentage land use classes of 2000GC

Source: Analysis of Satellite images, 2022GC

4.3.2. Land Use/Land Cover in 2007 GC

The land use land cover of the year 2007GC showed significant change for the land-use class of bare land by which its total area coverage reached 2521.35Ha (18.84%). This showed that bare land had increased significantly over the past 7 years. In these years' time interval agricultural land showed a relative reduction from the former year reaching an area of about 8125.56Ha (60.74%), while urban land and natural vegetative land showed an increase in their area coverage to a total of about 1658.61Ha (12.39%), and 1071.54Ha (8.01%) respectively.

Class Name (2007)	Area in Hectares	Area in Percent
Agricultural Land	8125.56	60.74
Vegetation	1071.54	8.01
Bare Land	2521.35	18.84
Urban land	1658.61	12.39
Total	13377.1	100

Table 10: Area and percentage of land use the land cover of 2007GC

Source: Analysis of Satellite images, 2022GC

4.3.3. Land Use/Land Cover in 2014 GC

After about 14 years the land use land cover change detection showed a continuous reduction in the Agricultural land with an area of 7473.6Ha (55.86%) followed by a slight reduction in area coverage of bare land from the former year to an area of 2137.41Ha (15.97). The natural vegetative land keeps on increasing in a small-scale and continuous increase each consecutive year with an area of 1231.29Ha (9.20%). Urban land significantly kept increasing each year becoming 2534.76Ha (18.94%) of area.

Class Names (2014)	Area in Hectares	Area in Percent
Agricultural Land	7473.6	55.86
Vegetation	1231.29	9.20
Bare Land	2137.41	15.97
Urban land	2534.76	18.94
Total	13377.1	100

Table 11: Area and percentage of land use the land cover of 2014GC

Source: Analysis of Satellite images, 2022GC

4.3.4. Land Use/Land Cover in 2021 GC

In the year of 2021 GC, the data obtained showed a great deal of reduction for Agricultural land from the past 14 years by more than half to total area coverage of about 4341.15Ha (32.45%). Urban land more than doubled in its area coverage from the year 2014 GC and held an area of 4823.46Ha (36.05%). The natural vegetative land kept on showing a relative increase that is hardly recognizable holding an area of about 1284.48Ha (9.60%). Bare land also exhibited an increase in its area coverage from the former year with an area of 2927.97Ha (21.88%).

Class Names (2021)	Area in Hectares	Area in Percent
Agricultural Land	4341.15	32.45
Vegetation	1284.48	9.60
Bare Land	2927.97	21.88
Urban land	4823.46	36.05
Total	13377.1	100

Table 12: Area and percentage of land use the land cover of 2021GC

Source: Analysis of Satellite images, 2022GC

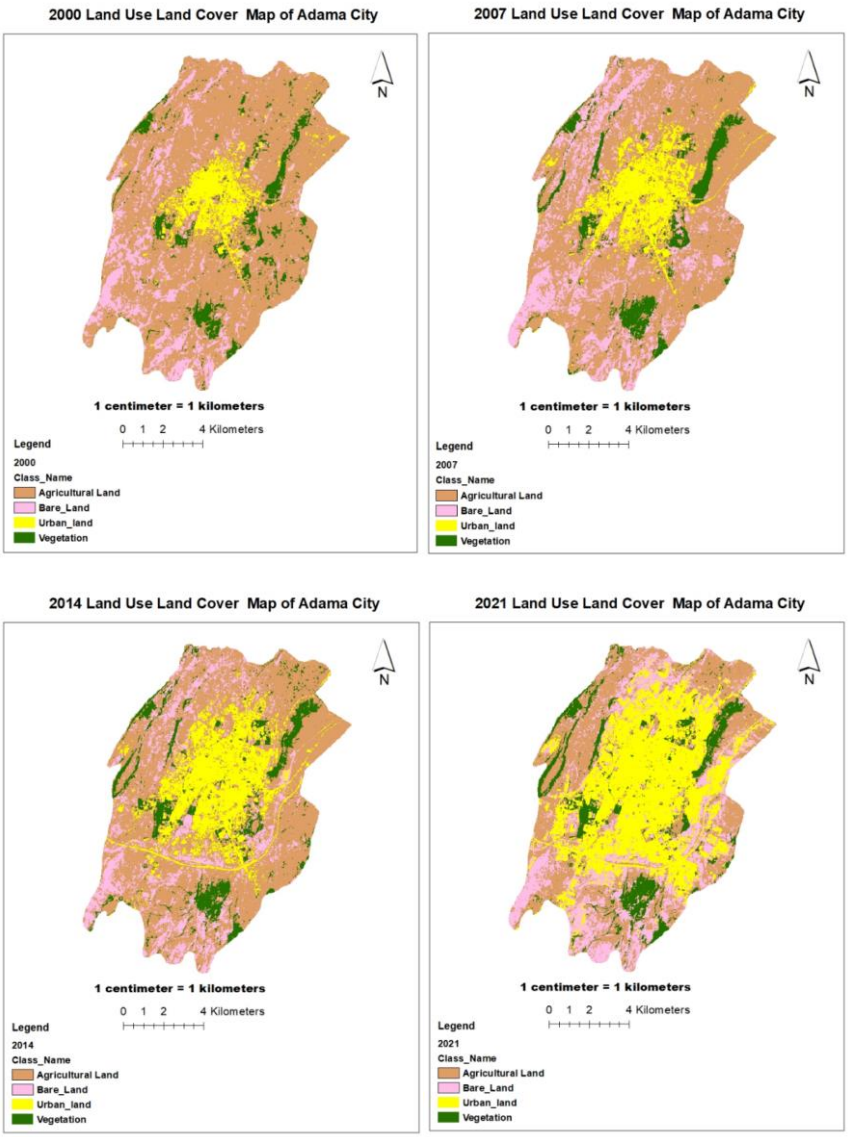


Figure 15: Land use land cover map of Adama city in 2000GC, 2007GC, 2014GC, and 2021GC,

Source: Researcher own Analysis, 2022GC

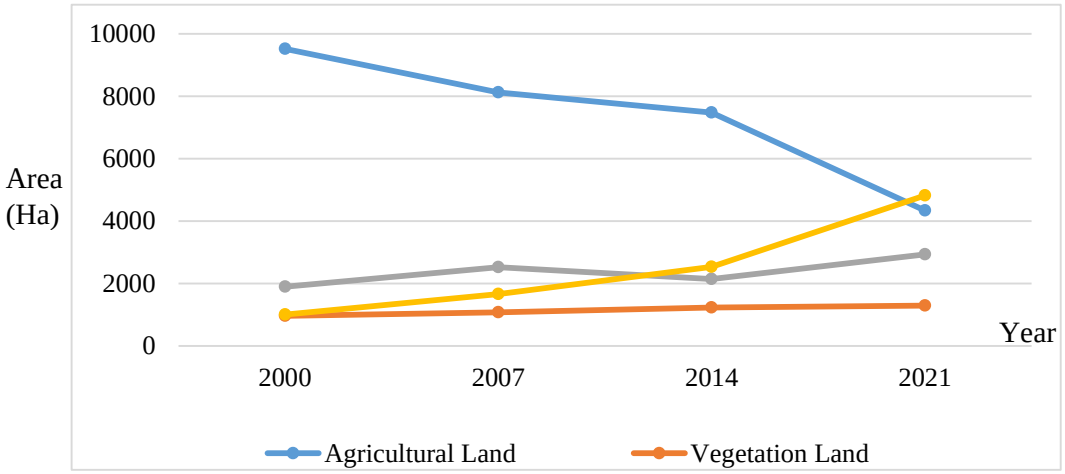


Figure 16: LULC change in Adama city from (2000 to 2021)

Source: Researcher own Analysis, 2022GC

4.3.5. Land Use/Land Cover Change of Adama City between (2000-2021) GC

The following tables show the overall change each class exhibited with each other and themselves.

Class name	Change (2000-2007)							
	Agricultural Land		Vegetation		Bare Land		Urban land	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Agricultural Land	6905	51.24	296	2.21	820	6.08	104	0.77
Vegetation	494	3.66	547	4.05	27	0.2	104	0.77
Bare Land	1435	10.64	100.1	0.74	984	7.3	1	0.01
Urban land	684	5.07	17	0.12	67	0.49	890	6.6

Table 13: Area land use land cover change from (2000-2007) GC

Source: Analysis of Satellite images, 2022GC

Class name	Change (2007-2014)							
	Agricultural Land		Vegetation		Bare Land		Urban land	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Agricultural Land	5962	44.5	244	1.82	1132	8.46	135	1.01
Vegetation	417	3.11	761	5.68	46	0.34	7	0.05
Bare Land	834	6.23	44	0.32	1249	9.33	11	0.08
Urban land	913	6.82	22	0.16	94	0.7	1505	11.25

Table 14: Area land use land cover change from (2007-2014) GC

Source: Analysis of Satellite images, 2022GC

Class name	Change (2014-2021)							
	Agricultural Land		Vegetation		Bare Land		Urban land	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Agricultural Land	3437	5.69	201	1.5	670	5.01	33	0.24
Vegetation	324	2.42	921	6.88	33	0.24	7	0.05
Bare Land	1744	13.03	45	0.33	1104	8.25	35	0.26
Urban land	1968	14.71	65	0.48	331	2.47	2459	

Table 15: Area land use land cover change from (2014-2021) GC

Source: Analysis of Satellite images, 2022GC

The land uses land cover changes were generated and classified through the images of the maps from the four consecutive years of seven years intervals that showed the changes in the land use classes. From the above tables, it can be observed that the different land use classes have shown amalgamation change from one class to another throughout the four

consecutive periods (2000, 2007, 2014, and 2021). From the year 2000-2007, the agricultural land showed an increased change into additional agricultural land while bare land showed significant conversion into agricultural land by which the change in hectares was recorded to be 6905Ha (51.24%) and 1435Ha (10.64%) respectively. The agricultural land, the bare land, and the vegetative land also showed a change in-to urban land by which the change in hectares was 104Ha (0.77%), 1Ha (0.01%), and 104Ha (0.77%) respectively. In the time interval from 2007-2014, the agricultural land, the bare land, and the natural vegetative land showed a slight change in to urban land by which the change in hectares was about 135Ha (1.01%), 11Ha (0.08%), and 315.45Ha (2.37%) respectively while urban land changed to urban land dramatically with a change in hectares of about 1505Ha (11.25).

In the years from 2014-2021 agricultural land and bare land showed a change into urban land in a smaller manner with an area of change of about 33Ha (20.38%) and 35Ha (0.26) while natural vegetative land showed a far less conversion toward urban land with a changing area of 7Ha (0.05%). Therefore, change occurs between these land uses unpredictably.

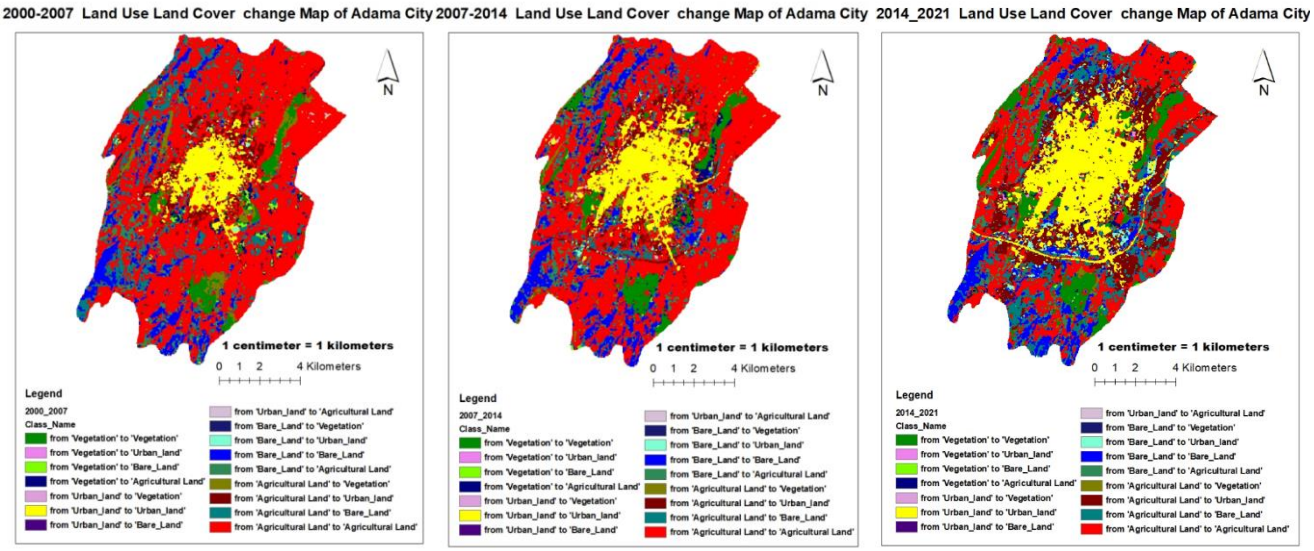


Figure 17: Land use land cover change map of Adama city in 2000-2021GC

Source: Researcher own Analysis, 2022GC

4.3.6. Land Use/Land Cover Change in (Ha) and Percent (%) Between (2000, 2007, 2014, and 2021) GC.

The land use land cover changes provided below show the change that occurred over the seven years of the chosen land use classes of the research.

Land use Class	2000		2007		Change form 2000-2007	
	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)
Agricultural land	9518.13	71.15	8125.56	60.74	-1392.57	-10.409
Vegetation	961.11	7.18	1071.54	8.01	+110.429	+0.83
Bare land	1898.37	14.19	2521.35	18.84	+622.98	+4.65
Urban land	999.45	7.47	1658.61	12.39	+659.16	+4.92

Table 16: Land use land cover map of Adama city in 2000GC

Source: Researcher own Analysis, 2022GC

Land use Class	2007		2014		Change form 2007-2014	
	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)
Agricultural land	8125.56	60.74	7473.6	55.86	-651.96	-4.88
Vegetation	1071.54	8.01	1231.29	9.2	+159.75	+1.189
Bare land	2521.35	18.84	2137.41	15.97	-383.94	-2.869
Urban land	1658.61	12.39	2534.76	18.94	+876.149	+6.549

Table 17: Land use land cover map of Adama city in 2000GC

Source: Researcher own Analysis, 2022GC

Land use Class	2014		2021		Change form 2014-2021	
	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)
Agricultural land	7473.6	55.86	4341.15	32.45	-3132.45	-23.41
Vegetation	1231.29	9.2	1284.48	9.60	+53.19	+0.4
Bare land	2137.41	15.97	2927.97	21.88	+790.56	+5.909
Urban land	2534.76	18.94	4823.46	36.05	+2288.70	+17.11

Table 18: Land use land cover map of Adama city in 2000GC

Source: Researcher own Analysis, 2022GC

As observed from the above Tables the recorded changes of the land-use class from 2000-2007, 2007-2014, and 2014-2021: Agricultural land dramatically decreases in its area coverage from an initial area of 1392.57 Ha (10.409%), 651.96Ha (4.88%), and 3132.45Ha (23.41%) respectively. Throughout the period Natural vegetative land showed a significant increase in the four consecutive years from 2000-2014 while a slight increase was observed in the last period from 2014-2021 from an area of 110.429Ha (0.83%), 159.75Ha (1.189%), to 53.19Ha (0.4%) respectively. Urban land was the land that showed a relative increase in

the years from 2000-2014 while showing an unprecedented rise in its land coverage in all years from 2014-2021 by which its area changed from 659.16Ha (4.92%), 876.149Ha (6.549%), to 2288.70Ha (17.11%) respectively. Bare land on the contrary showed an increase in the first year's period between 2000-2007 but reduced by double in the next years of 2007-2014 while finally increasing in the last period of the years 2014-2021 with an area of about 622.98Ha (4.65%), 383.94Ha (2.869%), and 790.56Ha (5.909%) respectively. Therefore, urban land positively increased over the study periods while agricultural land was highly reduced and affected by the growth of the urban land. Vegetative land also showed a slight increase while bare land showed fluctuation from increase to decrease to increase over the study period.

Summary of LU/LC change

As observed from the land use/land cover change detection of the four consecutive years the following findings have been provided as vital information concerning the changes that the city of Adama faced over the years.

- From the beginning of the study period in the year 2000GC, agricultural land was the dominant land use while the natural vegetation land was the minimum land use preceded by the urban land whereas the bare land was the second dominant land use.
- After 7 years interval, it can be observed that agricultural land showed a significant reduction in its area coverage while the other land use classes that included natural vegetative land, and bare land showed a relatively smaller increase with slight variation from the former years were as urban land showed a relatively higher increase which is somewhat noticeable.
- In the third consecutive year of the study period which is the year 2014, agricultural land keeps on declining while bare land also exhibited a slight reduction that is hardly noticeable in their area coverage. Natural vegetative land and urban land showed a relative increase and a staggering growth respectively.
- In the fourth and final study year of 2021, the land that still kept reducing was the agricultural land while the other land uses including the natural vegetative land, the bare land, and the urban land still kept on increasing with slight and almost unnoticeable change, increase from the previous year and dramatic increase almost doubled form the former year respectively.

4.3.7. Impacts on the Land Use Classes (Urban Land, Agricultural Land, Natural Vegetative Land, and Bare Land)

Urban Land

It is evident that the growth of a city and an urban area brings about different benefits to the conditions of the city due to the rise in opportunities through employment opportunities, better health care, enhanced living condition provisions, innovative and technological advancements, basic infrastructural availabilities and so on through the city's expansion to its surrounding area both vertically and horizontally. Even if, a city is expanding vertically, the majority of the expansion occurs horizontally through excessive land consumption. But the benefits of a city's growth create their implications for the impacts observed on the surrounding areas and their features include the agricultural areas, the vegetative areas, and the existing bare lands.

As a main factor for development urbanization has its own positive impacts that can change a city socially, spatially, economically, culturally, politically and so on by being a hub for knowledge, employment opportunities, better life quality, health cares and educations and improved service and infrastructure availabilities to the population of the city (Coulibaly, 2020).

From the data obtained through land use land cover change detection, it can be observed that the urban land has shown a significant amount of increase through the study periods of 2000-2021 in Adama city. At the begging of the study period of the year 2000, the urban land was the third dominant land-use class succeeding the land use class of bare land which is then succeeded by the major and dominant land use class agricultural land. The urban land continued to grow in the following consecutive years showing a staggering increase in its area coverage. This shows that the urban land has increased through the physical expansion towards the surrounding land which has become and will become a risk for the other land uses surrounding the city because it is seriously consuming land as it expands. The surrounding green belts i.e., Agricultural land, and natural vegetative land are being consumed through the physical expansion process.

Agricultural Land

Agriculture has been and is the backbone for many developing countries including Ethiopia's economy. When agricultural land is overtaken by the urban areas, there is an

increasing lack of food security for the citizens related to reducing productivity, relocation of people from their lively hoods, and increased unemployed manpower among others.

The negative impacts of urbanization can be the loss of agricultural land that can be an ever-increasing concern that will affect the food provision to the livelihoods of both the urban farmers and the citizens that will result in under production of economic growth of a city (Coulibaly, 2020). And in countries such as Ethiopia the dominant majority of the population is highly dependent and employed in agriculture making land an important economic resource (Assefa, 2020).

As the land use and land cover change detection and analysis indicates, Agricultural land was the land-use class was the superior class at the beginning of the study period of 2000 but as observed from the land use/land cover change detection it is declining remarkably throughout the study periods of 2007-2021 in Adama city. It can be concluded, therefore, that agricultural land is being consumed and changed to the other land use classes which is a great problem as the city's and country's main economy is based on agricultural production.

Natural Vegetative Land

Natural vegetation includes natural and native features of vegetation that are existent in an area growing mostly on its own. These vegetations have acted as natural barriers against desertification, erosion, landslides, flooding, and protection of existing biodiversity of both animals and plants and so on. The effects of landslides, erosions and soon are combated by vegetation as the roots of these plants hold the soil together stabilizing it (Rabby, 2022)

From the data acquired through land use/land cover change detection of Adama city, the natural vegetative land-use class is the class that has increased throughout the study periods of 2000-2021 but the increase is slight, steady, and almost unnoticeable and compared to the urban land its area coverage is hardly recognized. It can be observed that the growth rate of vegetative land is not balanced with the growth of the urban land and that vegetative land is not increasing as it needed to indicate that there is still a need to counterbalance the vegetation requirement with the increasing urban land.

Bare Land

Bare land as the name indicates is barren that has little to no features and vegetation. In the land use, land cover change detection of Adama city form the years 2000-2021, this piece of land is a land that has shown a significant increase on the second period (2007) interval compared to the former year (2000) interval but reduced in the third interval (2014) finally

increasing in the fourth interval (2021). It can be observed that bare land is growing which means that land is being left barren more and more as the city continues to grow. As the urban built-up area consumes land that is occupied once by agricultural land, and or vegetation a parcel of land is left barren. Leaving an area barren can have an implication of creating erosions and landslides, flooding, desertification, and other environmental hazards.

4.4. Proposed Plan and Vertical foresting design at Adama city's Expansion Site

Adama city has been proven to be a city experiencing a significant population and territorial increase that has led to the redefinition of existing land uses into urban built-up areas which have resulted in significant environmental degradation and deterioration. Sustainable systems that integrate the natural environment with the urban environment through the provision of urban greening systems are measures that can be taken to protect and preserve the urban ecosystem and the environment. Provision of urban green infrastructures can be accomplished through many measures mainly the protection and preservation of existing surrounding and neighboring green belts of the city that can be accompanied by the planting of trees and different plant types within and around urban areas; preserving and providing urban agricultural areas as well. The main aim is to bring the natural environment into the city to integrate and interlink the city and the environment sustainably to compact unsuitable microclimatic conditions, air pollution, noise pollution, improve the physical and psychological health of citizens, and improve the standard of living in the city.

The city of Adama has provided 4 standard expansion sites in its structural plan of the city that are put for further expansion of the city but currently, the expansion areas are also observed to be faced with consumption of their lands because of the city's rapid expansion. By basing its foundation on the result acquired through the research study, the proposed plan is concerned with the creation of a vertical foresting design at Adama city's expansion site commonly referred to Dhaka Adi expansion site. The result of the research study has displayed that the surrounding green belt of Adama city i.e., agricultural/farmland, bare/open land, and vegetative land has been significantly changed in due course of time but were dramatically altered during the past 20 years by which each land was invaded by the physical expansion of the urban center of the city. Therefore, the proposed planning and design are aimed at providing a solution or mitigation action for the impacts faced by the surrounding green belt.

4.4.1. Analysis of Development Conditions

Structural Plan of Adama City

There are several plans in place for the development of Ethiopia which Structural Plan is among one of those plans. These plans are valid for 10 years from their date of approval and are guided by the regional and national development plan schemes.

Land use plan

Adama structural plan is categorized into land-use classes namely: Commerce and business (centers and market areas); Mixed-use (mixed land use and buildable area); Green/Park; service (Social, Cultural, general, Utility, Municipal, and public squares); Urban Agriculture (farmland, horticulture and Ground Water Protection); MSC (manufacturing and Storages); Administration (special Administration centers and Government Offices); Housing Expansion area; Transport Terminals and Roads. The structural plan indicates that the surrounding areas of the city are mostly proposed as expansion sites hence the project site is located on one of the expansion sites of the city in the North-Eastern part of the city known as Dhaka Adi expansion site.

The project site is allocated as a residential land use area by the proposed structural plan of the city which shows that the land will be further developed soon. Due to the increased urbanization, the project aims at reducing the land consumption that will occur at the Dhaka Adi expansion site which has shown a significant rise in its land consumed. The project site was developed with consideration to the mitigation of the environmental impact that has occurred in the surrounding areas due to the physical expansion of the city.

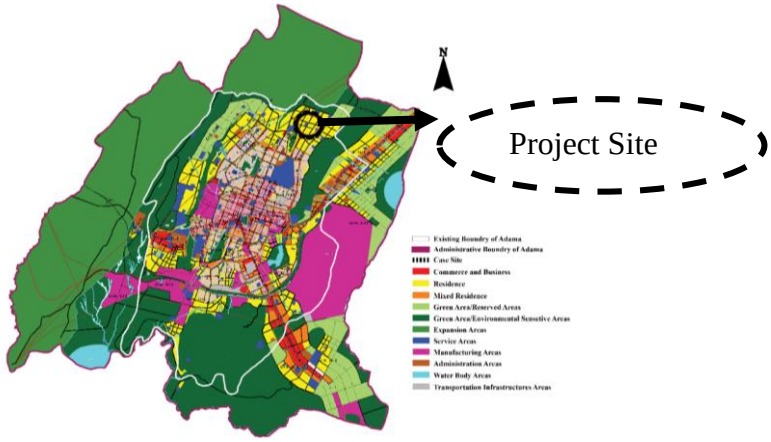


Figure 18: Proposed Structural plan of Adama city

Source: Adama City Land Administration Office

Road Network

Based on the Structural plan of the city of Adama the project site is located 2km from Tekle Haymanot square and 7km from Derartu Square (Posta Bet). The existence of these roads shows that the site is accessible and road infrastructures are already provided around the area. Even though the project site is located on the near outskirts of the center of the city it is still accessible towards the center of the city through these roads.

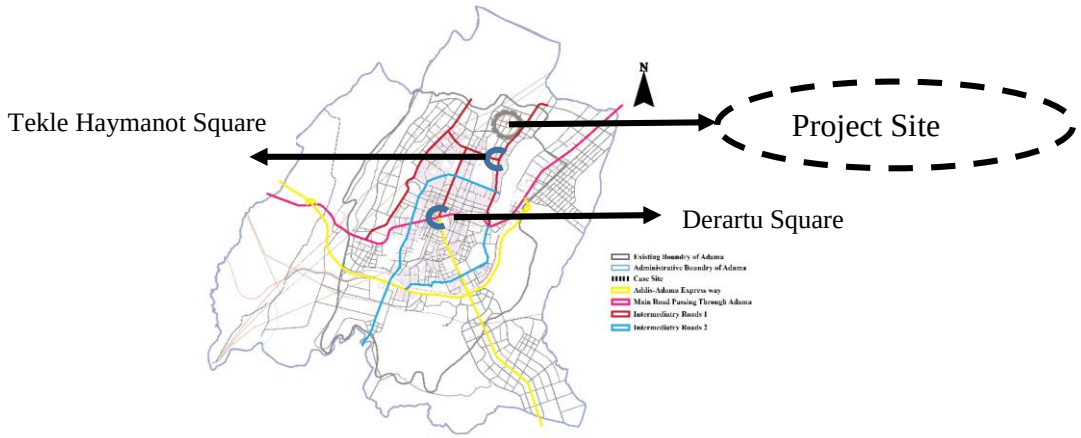


Figure 19: Road Network of Adama city

Source: Adama City Land Administration Office

4.4.1.1. Site Assessment for the Vertical Foresting Expansion Site

The project site covers 12 hectares and is located in the North-Eastern part of Dhaka Adi Expansion site (1320 Hectares) close to Adama Science and Technology University. The project takes into consideration the existing as well as the future shape of the expanded city. The expanded city will either compact or elongate in its shape. The project site is observed to be compact in its shape which will reduce the cost required for infrastructures to be provided such as; Road networks, Electric lines, Drainage networks, and so on. It will also; Minimize time travel to the site, have easy proximity to urban services, proved public space, and proved easy exploitation of new urban technologies.

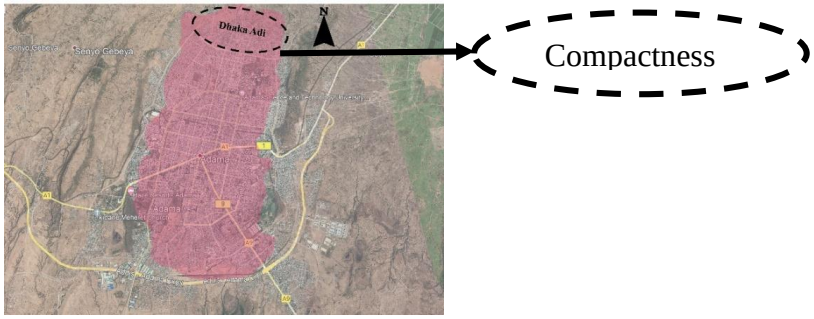


Figure 20: Shape of Expansion Site of Dhaka Adi

Source: Researcher's own survey

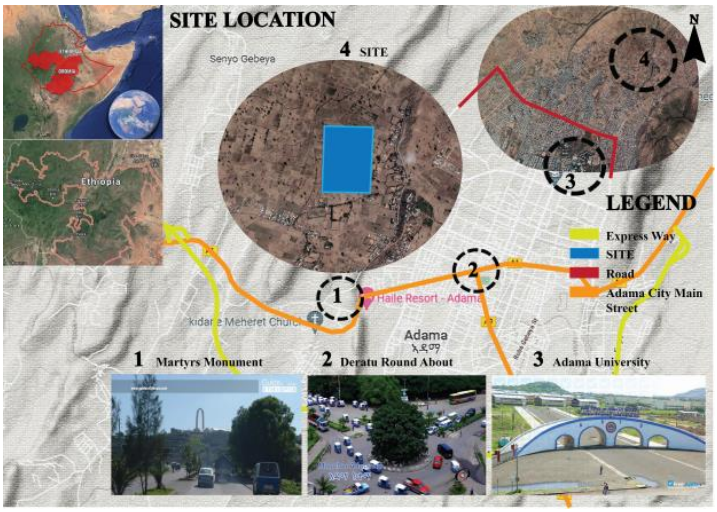


Figure 21: Location Map of the Project site
Source: Researcher's own survey

Action and Planning Area

The general purpose of action and planning areas plans is to ensure that development is undertaken in a sustainable and integrated manner. Action and planning areas are used to determine the extent of the site for which the plan is prepared and the area which has a direct/indirect effect on the study area respectively.

The planning area refers to the geographic area covered by the plan and it is selected based on factors that would positively and/ or negatively affect the action area during the planning and design of the project. It is important to identify problems and opportunities, development, and management strategies in the planning area. The planning area is about 500m in each direction from the action area to analyze the surrounding existing conditions. As is shown in the figure below, the site is agricultural land in the Northern and Western parts and has scattered settlements in the Eastern and Southern parts.

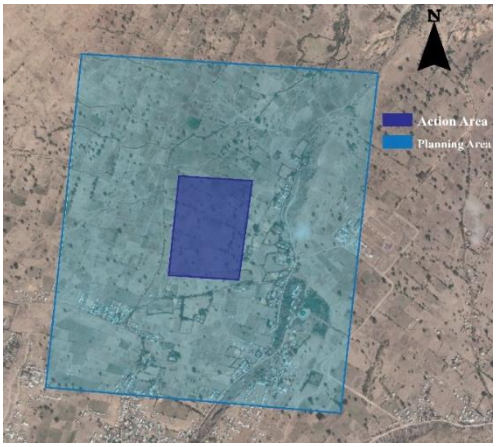


Figure 22: Action and Planning Area
Source: Researcher's own survey

4.4.1. Case Site Condition

4.4.1.1. Natural Condition

Contour Line Analysis

Contour is a line map that represents an imaginary line on the land surface. It is drawn on a map connecting points of equal height and equal elevation. Numbers on the line give the height in meters. The lines drawn closely together indicate that the slope is steep while lines drawn further apart indicate the slope is flatter.

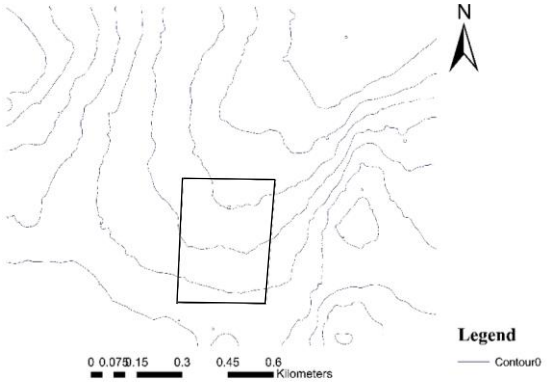


Figure 23: Contour Analysis

Source: Researcher's own survey

Elevation

The project site elevation ranges between 1668m and 1687m. the land gradually becomes higher from the North-East towards the South-West.

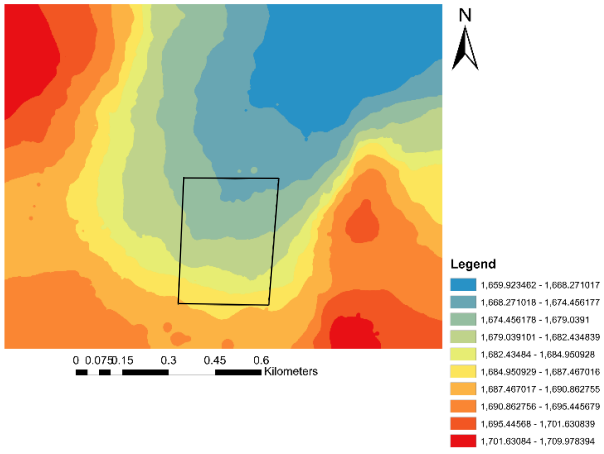


Figure 24: Analysis of Elevation Map

Source: Researcher's own survey

Slope Analysis

Slope analysis of the project site reveals that more than 85% of the site is flat and gentle sloping which is comfortable for farming as well as a large-scale housing development.

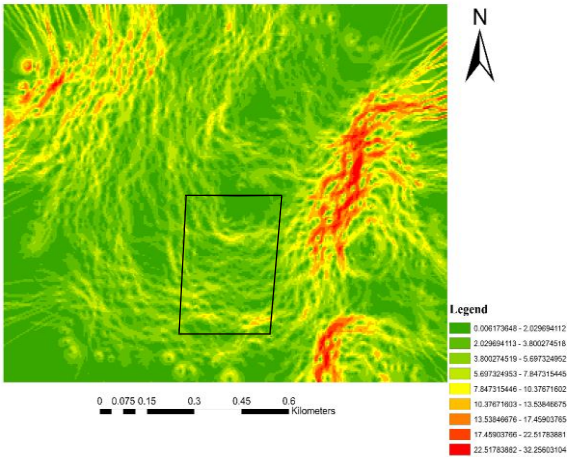


Figure 25: Slope Analysis

Source: Researcher's own survey

Soil Type

The project site's soil type includes sandy and loam soil with a color type of black and brown. The existence of both soil types creates a better opportunity for construction and greenery purposes.

Vegetation Type

There are various types of plants located on the project site by which most of the plants are grown by default while some of these plants provide shading purposes. The common plant types include; Acacia, Pricly, Bramble, Eucalyptus, And Tikure

.

Figure 26: Plant Types in Project site

Source: Researcher's own survey

Wind Direction and Sun Path

The wind direction of the project site is the North-Easterly direction. The noise direction is from the West and the South.

Figure 27: Wind Direction and Sun Path analysis

Source: Researcher's own survey

4.4.1.2. Existing Land Use Plan of the case Site

The existing synthesized land use plan of the project site is majorly farmland and scattered trees and vegetation.

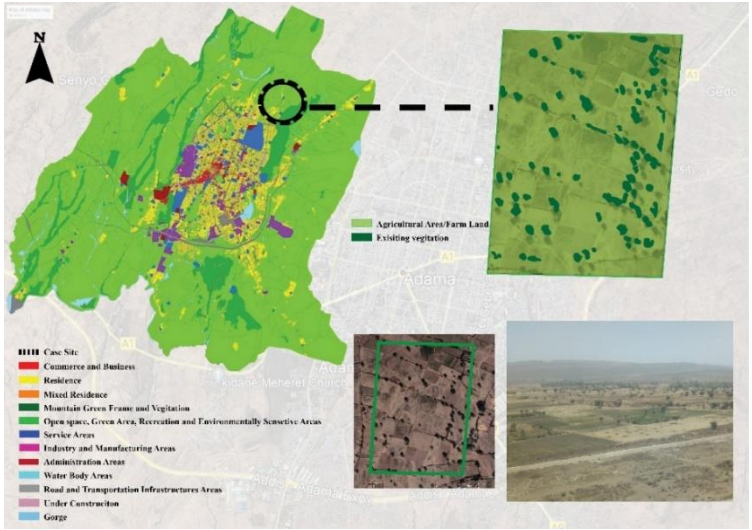


Figure 28: Existing Land Use Plan of case Site

Source: Researcher's own survey

4.4.1.3. Existing Land Use Plan of the case Site and Surrounding Features

Among the land use around the site, farmland and bare land occupy predominantly the existing area. Scattered residential areas and some services are located in the Eastern and Southern parts of the surrounding area.

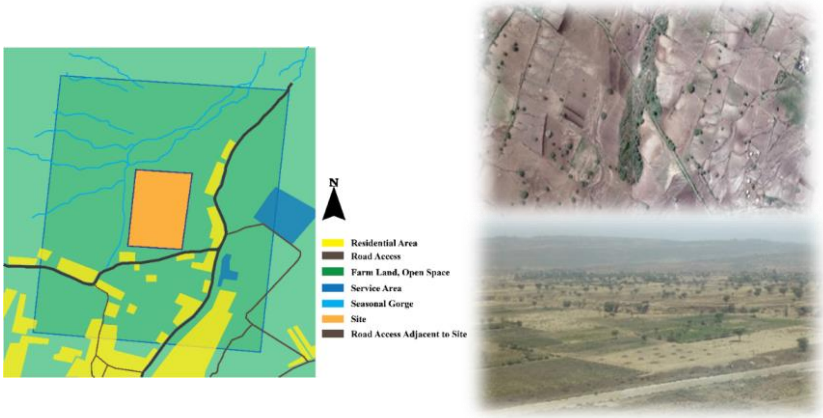


Figure 29: Existing Land Use Plan of case Site

Source: Researcher's own survey

There are several existing residential villages around the project site. The villages have been getting scattered and new residential communities have been expanding towards the Northern area of the site

Figure 30: Morphology Map of case Site

Source: Researcher's own survey

4.4.1.4. Existing Physical Infrastructures

Existing Road Network

The project site and its surroundings do not have a proper track path. Some roads don't follow the standard road requirements and are unpaved or natural roads mainly created by footpaths of locals. The materials of the roads are muddy and dry. There existing adjacent roads are running from the North-East to South-West and from East to West. Even if the

roads are available, they don’t have proper maintenance and therefore are difficult to walk through during the rainy season. The lack of standard access to units is a problem for many residents in this neighborhood.

Figure 31: Existing Road Network Map of case Site

Source: Researcher's own field survey

Water Supply

The Awash River is the most utilized river among Ethiopian river basins and serves as Adama city’s water supply, source of irrigation, and hydroelectric power. Adama city administration has two macro watersheds which are Awash and Migira Macro-watersheds. The current water demand of Adama city in million m^3 per year is 14.4 million m^3, whereas the existing production supplied excluding leakage is 7.24 million m^3 per year. This implies that the difference between demand and supply in million m^3 per year is 5.35. It is estimated that about 20% of the shortage of water in Adama is due to leakage. Even if there is a water supply around the project site there is a lack of proper access to the residents of the area.

Electric Power Supply

Adama city’s first electric power supply was started in 1936EC as a self-contained system. Since 1953 the city has been supplied by a national grid that is an interconnected system and has an adequate electric power supply. The project site has electric lines which show it has an availability of power supply.

Waste Management

The project site and its surroundings there is no organized and proper waste management practice i.e., lack of proper waste collection system for both solid and liquid waste, lack of appropriate waste disposal site, limited concern/awareness and carelessness of the community, and weak enforcement of rules and regulations.

4.4.1.5. SWOT Analysis

Strength

- According to the structural plan of Adama city, the project site is allocated as a future urban expansion site. Currently, the city has selected the project site for residential development.
- Most of the land consists of farmland and vacant land which means the site is easy to develop.
- The project site is located 7 km away from the city center and 5 km away from the Addis-Adama expressway which shows the Project site has good accessibility to the city center.
- The project site is gentle slopping with good topographic features that are beneficial for construction purposes.
- There is the availability of nearby electricity and water supply.
- There are already provided roads which show the site's easy accessibility.

Weakness

- Due to the poor capacity of infrastructures inside the project site, new infrastructures need to be constructed.
- Adjacent main arterial roads and access roads are insufficient.
- There is a shortage of potable water supply.
- There is a lack of access roads with the proper width, surface materials, and drainage channels.

Opportunity

- The project site is an expansion site which gives it a great opportunity to be further developed.
- The project site has an untouched piece of land opportunity for new constructions and businesses
- The Project site is expandable because of the availability of land.

Treat

- Susceptibility to flooding in the site due to flat surface

4.4.2. Concept Plan Development

The most important feature of any Ethiopians' life is their Family which forms the core of their support network with their relatives and their neighbors as they are interdependent on one another in their day-to-day lives. This shows that Ethiopians are a highly communal group of people which is observed in their entire culture. The Oromo people are among one the nations of Ethiopians that practice a strong sense of family and communal life. In the life of any Oromo citizen values of community and neighborhood is an important social network interconnected to each other through extended family and friends. They are a highly communal group of people who work and solve problems together under a respectful and selected group of people which is a common peace resolution method in these communities, this is shown in their great tradition known as The Gada System which is a traditional and indigenous institution that is prevalent in every aspect of any Oromo citizens life which includes his or her social, economic and political life characterized by peaceful coexistence with the Oromo people themselves as well as peace with other communities, with their natural environment and with God.

Figure 32: Typical Ethiopian family structure and the Gada system

Source: Google Images

An Ethiopian family lives in a household under the same roof together but soon parts of the family will venture out and create their own families which are observed in the children of the family after they are grown. As more family members move out to make their livelihoods, the consumption of land is increased. The concept of this project focuses and depends on collecting and gathering the segregated family generations under an area for regenerating the land consumed and changed through the conceptual base of the Gada system. Among the main features of the Gada system, the main prevailing feature is their habit of gathering together to solve their problems under a group of great leaders and a great natural tree. This is evidence that gathering together will provide a solution and that nature is our main shelter.

Based on the Gada system concept, the current problem that Adama city is facing which is the excessive land consumption due to the expansion of households will be reduced as families are gathered together in a smaller and well-developed parcel of land rather than living in a larger land which they used to do before.

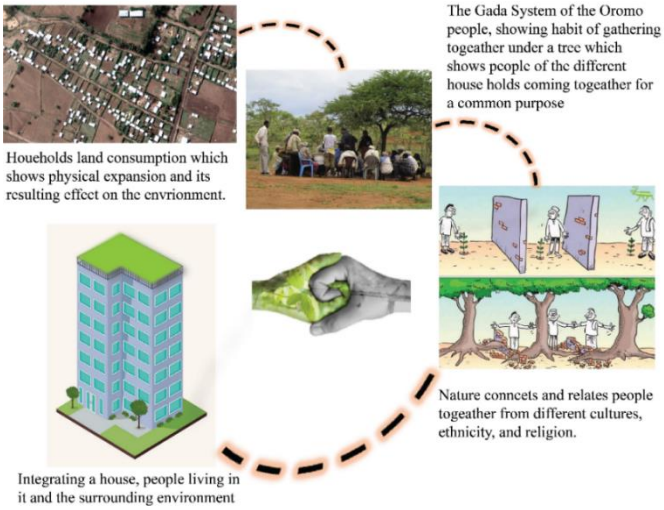


Figure 33: Concept of the Design
Source: Researcher's own computation

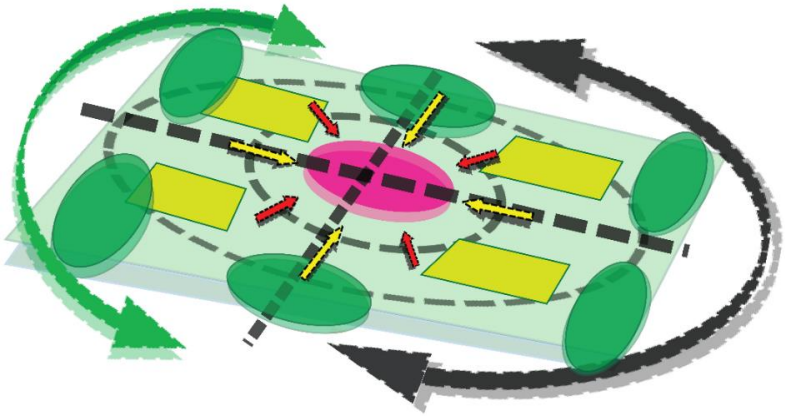


Figure 34: Concept Development
Source: Researcher's own computation

The concept works in creating a central core element that links all other elements and an interlinked area. As the culture of the community indicates the design works in the connectedness of services. The concept also clearly declares the importance of greeneries and their great impact on saving the environment and collecting the community under its wings.

4.4.3. Vertical Foresting Expansion City Design

The goal of the design is to create Accessibility, Environmental Sustainability, and Communality. Vertical foresting is a system of integrating humans with the natural environment in a symbiotic manner. Features the design include

Accessibility

Accessibility is described in terms of access to services provided and mobility through street access.

Mobility through street access includes

- Provide pedestrian-oriented access streets and bike lanes taking into consideration the disability of users.
- All services provided on the site are at 5 minutes' walk from their initial starting point.
- Highly emphasizes pedestrian-oriented movement.

Access to services provided includes

- There are basic infrastructures provided on the site such as electricity, clean water, telecommunication, proper waste treatment systems, services, and so on.
- There is also the provision of services such as green infrastructures including garden and farm areas for consumption purposes.

Environmental Sustainability

- The core element of the site is centered on giving more emphasis to the urban green infrastructure provisions. The site and its infrastructures such as service areas, buildings, and others are seen to emerge from the total green that covers it.
- There are open spaces, greenery areas, farm areas with different vegetation types, buildings have provisions of green roofs, green facades, balconies have greeneries, there are greenhouses that house various vegetation, and the site is surrounded by a natural park area that consists of different species of trees and plants. These plants are locally available and some of them are from other countries.

Sense of community

- The site is centered on linking the community and society living in it to increase connection and interaction.
- There is a provision of open spaces, centers, and squares that serve the purpose of collection and interaction with society.
- Different open markets and shops, amphitheaters, playgrounds, and open spaces exist to serve society and create connections among society.
- The different green infrastructures are directly available to the society of the site and aid in the society's interaction.

4.4.3.1. Vertical Foresting Expansion City Design Description

The vertical foresting expansion city located on the outskirts of the Dhaka Adi which lies in a total area of 12 ha is a city plan that implements vertical foresting. The site is located 1.8km away from the education institution known as Adama Science and Technology University. The site is surrounded by scattered settlements and a church. The site will house the creation of residences, commercials, shops and markets, recreation areas, open spaces, social gathering areas, schools, wellness centers, and clinics all centered on a vibrant green and natural environment. The building typologies are four in type in the built-up area of 31,324 sqm.

The site focuses on creating a greener space where people might inhabit and live in. The surface of the site will be dominantly covered by pedestrian ways. Basements exist in the buildings for purposes of car parking. There is a car parking area provided but the site does not allow the movement of vehicles inside its compound as it is solely pedestrian-oriented. There is a bus station which serves for transportation of the community to the main part of the city. The site has the provisions of basic green infrastructures such as open spaces, green areas, greenhouses, parks, and farm areas. The site includes different species of trees and plants to give the sense of a natural forest area.

Service Network

Number	Facilities found	Facilities included and use of the facility
1	Education	K - 8 schools
		Art school and literature schools
		Day-cares
2	Wellness Centers	Clinics
		Pharmacy
		Fitness centers
3	Services	Waste Treatment plant
		Libraries
		Bus Stations
		Service area
		Commercial centers, shops, malls, Open market
		Security stations
		Beauty Salons both male and female
		Restaurants, cafes, hotels
4	Central square	Community spaces, and cultural center
		Street furniture
		Pedestrian Sheds
		Sitting and recreational area and gathering area
		Fountains and greenery areas
5	Secondary Square	Sitting and gathering area
		Street furniture

		Greeneries, street furniture's for recreational purposes
6	Amphitheater	Entertainment, Gathering area
7	Playgrounds	Children play area
8	Park	Relaxing, recreational, gathering, and interacting area
		Street Furniture
9	Green House	Consists of different vegetation types, places of relaxation, and education

Table 19: Building Land Use, Service Zones, and Building Height

Source: Researcher's own computation

Land Use of the Site

The site is composed of 13 land-use types including road and pedestrian accesses. The land uses are building area (7831sqm*4), central squares; Main and sub squares (2206 sqm and 380sqm respectively), farm areas (8623sqm), parking space (2949sqm), service area (3339sqm), playground (1958sqm), amphitheater (2372sqm), greenhouse (1608sqm), greenery space (84,813sqm) and Main Road and Pedestrian roads (25,601sqm).

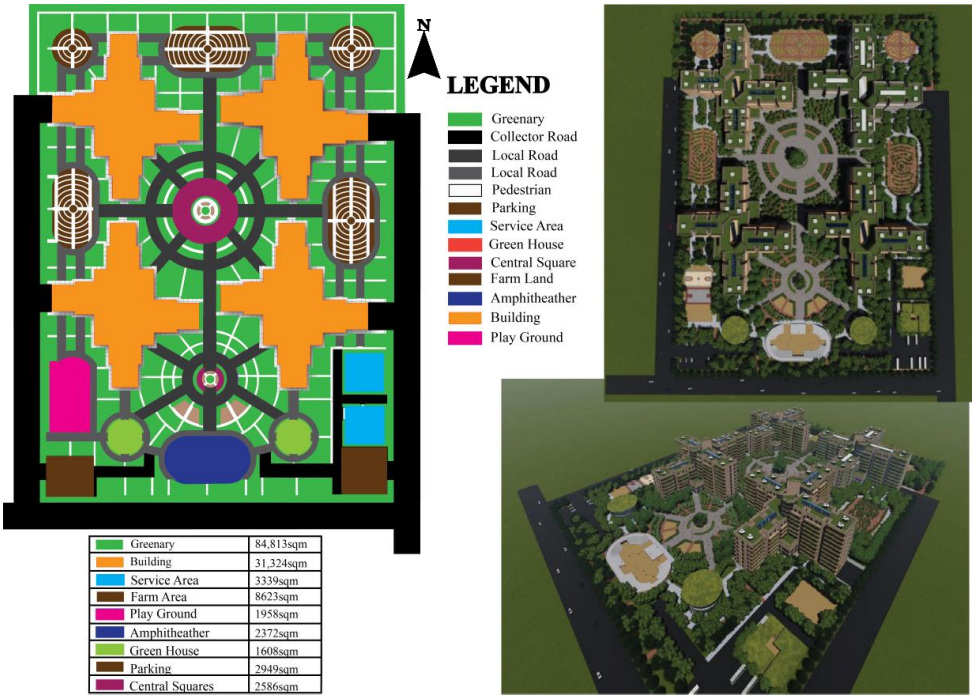


Figure 35: Land Use Map

Source: Researcher's own computation

Building Land Use

The site is composed of 4 building typologies that have residences of 3-bed rooms, 2-bed rooms, 1-bed rooms, and studio complexes. The building's ground, 1st, and 2nd floors include different services such as shops, malls, schools, and hotels while the 5th and 6th floors include services such as clinics, wellness centers, and services. The buildings have four levels which have 7 stories, 8 stories, 9 stories, and 10 stories. The single building area is 7831 sqm with

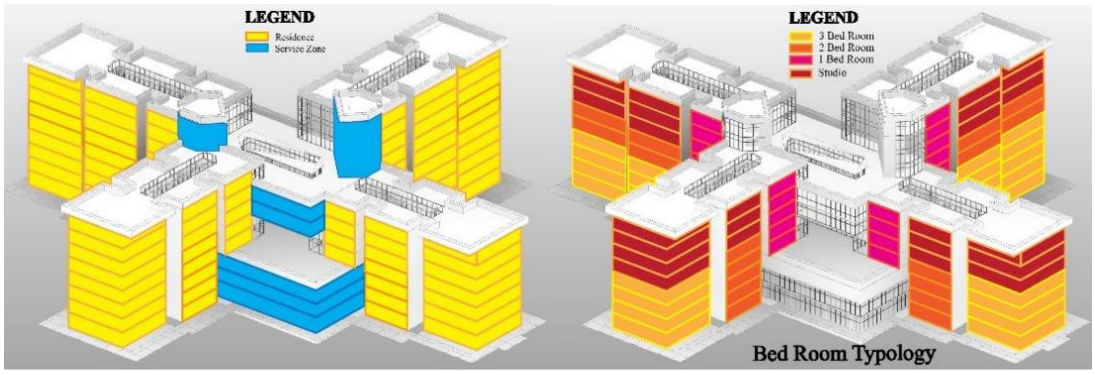
all four buildings' built-up area being 31,324 sqm. Two building typologies hold about 436 households while the other two buildings hold about 510 households and the total number of households provided is about 962 households. On the site, the proposed households are composed of (63) 3-bedroom complexes, (79) 2-bedroom complexes, (100) 1-bedroom complexes, and (241) studio complexes.

Building House Hold

Building	Building Typology Complex	Building Household Number			
		Block 1 (G+8)	Block 2 (G+7)	Block 3(G+6)	Block 4(G+9)
Building A, and B	Studio	24	30	24	28
	1 Bed Room	14	10	8	14
	2 Bed Room	8	10	8	8
	3 Bed Room	16	7	8	7
	Total	60*2	56*2	48*2	54*2
Building C and D	Studio	34	35	32	34
	1 Bed Room	15	15	12	12
	2 Bed Room	10	15	8	12
	3 Bed Room	8	5	6	6
	Total	67*2	70*2	56*2	62*2
Total House Hold in the site		962			

Table 20:Building household number

Source: Researcher's own computation



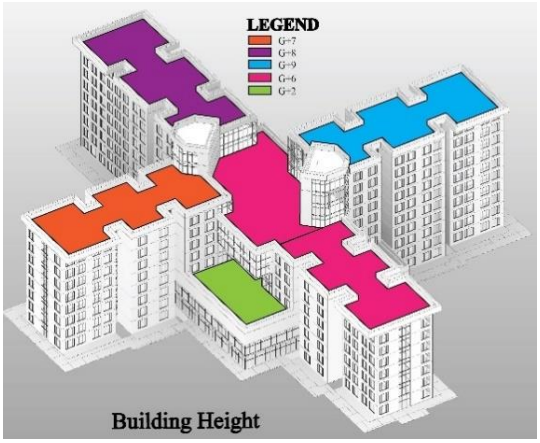


Figure 36: Building Land Use, Service Zones, and Building Height

Source: Researcher's own computation

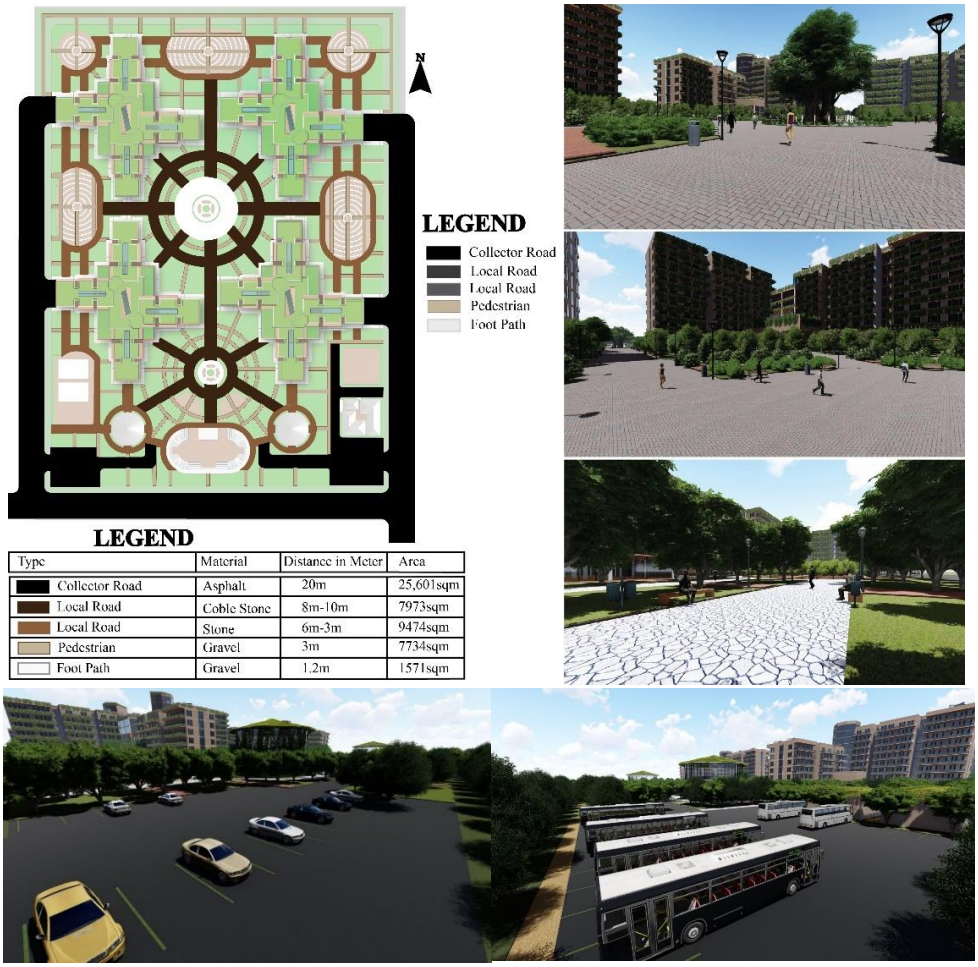
Figure 37: Site 3D image

Source: Researcher's own computation

Road Network of the site

The street network is majorly pedestrian-oriented. The pedestrian way access is focused on both pedestrians and bicycles. The street networks connect the areas to a central square where people gather and interact at. The street networks are the main road with a material of Asphalt and width of 20m, the intermediate pedestrian road with a material of coble stone and width ranging from 8m-10m, sub pedestrian road with a material of stone and width

ranging from 6m-3m, sub-sub pedestrian with a material of gravel and width of 3m and footpath with a material of gravel and width of 1.2m.



LEGEND

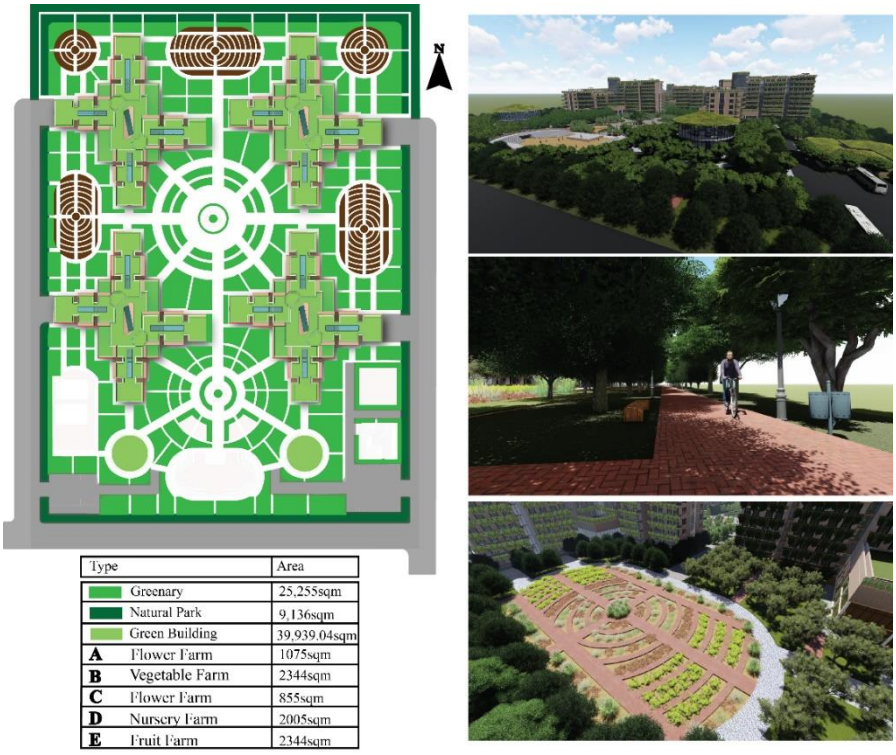
Type	Material	Distance in Meter	Area
Collector Road	Asphalt	20m	25,601sqm
Local Road	Coble Stone	8m-10m	7973sqm
Local Road	Stone	6m-3m	9474sqm
Pedestrian	Gravel	3m	7734sqm
Foot Path	Gravel	1.2m	1571sqm

Figure 38: Road Network Map

Source: Researcher's own computation

The greenery of the Site

The site is majorly composed of a green environment to emphasize the environment. There are different green infrastructures provided on the site which include basic green spaces with different greeneries and grass materials, small shrubs and flowers alike (25,255sqm), and a greenhouse that houses different species of plants (1608sqm). There are also farm areas (8623sqm) and a park that houses different species of trees and plants resembling a natural forest area that surrounds the site acting as a buffer as well for the site (9136sqm).



Type		Area
	Greenary	25,255sqm
	Natural Park	9,136sqm
	Green Building	39,939.04sqm
A	Flower Farm	1075sqm
B	Vegetable Farm	2344sqm
C	Flower Farm	855sqm
D	Nursery Farm	2005sqm
E	Fruit Farm	2344sqm

Figure 39: Greenery Map

Source: Researcher's own computation

Building Greenery

The building is covered with different plants and trees by which both vertical greening systems such as green facades, green walls, and green balconies and horizontal greening systems such as green roofs. The vegetation provided on and around the building is taken care of by the community of the site

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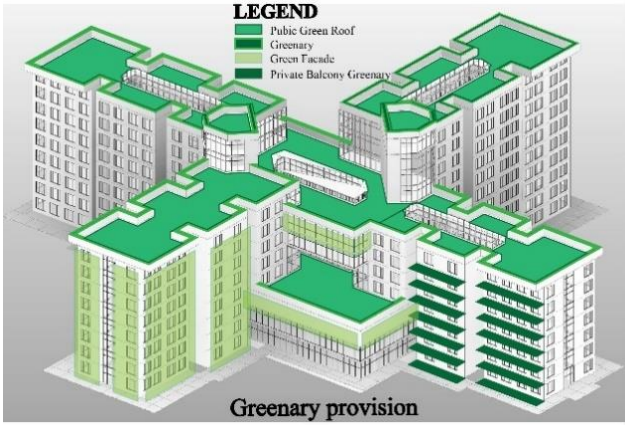

Figure 40: Building Greenery

Source: Researcher's own computation

Building Integrated Vegetation in Vertical Foresting Expansion City Plan

Vertical foresting is not only a system of environmental sustainability but also a way to reduce urban sprawl. They are also capable of cleaning the air by absorbing carbon dioxide from the atmosphere and releasing oxygen which is the result of having plant and vegetation covers. Vertical forests provide cities with a natural feel by integrating the natural environment with the built environment of the city, they help in preserving biodiversity, and aid in the treatment of people physically and psychologically.

The integration of vegetation in the building and the city can enhance the city's livability as it is a beacon for providing environmental sustainability. Vegetation can be provided both indoors and outdoors from the building and its surrounding. It can also be provided vertically and horizontally on the building. There are different methods employed to integrate vegetation into the site. These systems include elements such as Naturalistic Park, Public squares, Pedestrian greenways, Vertical green spaces, and Farm areas. The project provides different greening systems by focusing on showing how these systems can be done in simpler ways to create a better understanding and implementation by the community of the site.

Green façades - The green façade is among one of the vertical greening systems of buildings under the Green Wall system. The green façades are created in such a way that the plant is planted on the ground and allowed to grow upwards either by using the wall itself as support or by using other support systems attached to the wall. They serve as noise, and heat insulators, help increase oxygen provision and give mental relaxation to the users.

Green Balconies - These are vertical greening systems of building commonly linked to terms of Green Terracing as a balcony is sometimes referred to as terraces. This system can be implemented by using a system to plant the vegetation on the balcony and by using plants and vegetation planted in pots.

Green Wall - Green walls are one of the vertical greening systems that are applied to the walls of buildings. The wall is covered with different substrates to protect the wall from water and root penetration from the vegetation planted on it. They are good heat insulators and give a natural feel both indoors and outdoors of the building.

Green Roofs - Green roofs are horizontal greening systems applied on the roofs of buildings. These greening systems aid in reducing the temperature of the building, provide better insulation of sound and heat, reduce the urban heat island effect created by buildings, etc.

Figure 41: Building-integrated Vegetation

Source: Researcher's own computation

Farm Area

The farm area is composed of different species of vegetation and includes a flower farm, a vegetable farm, a fruit farm, and a nursery farm which lie in a total area of 8623sqm. These farm areas are public and accessible to the community of the society which is available for domestic use by these communities. The community is charged with the care of these farm areas which not only provide food but also employment opportunities for the caregivers. Each farm is unique and holds different species of vegetation they have.

Flower Farm

A Flower Farm is a farm area where different flower species are grown and visited by the community. The total area coverage is about 1930sqm. These areas are taken care of by the community as are all the other farm and green areas on the site. Flower farm includes different native species of flowers such as those provided in the figure below:

Figure 42: Flower Farm

Source: Researcher's own computation

Vegetable Farm

The vegetable farm is an area where different vegetables are grown and used for consumption purposes by the community of the site with a 2334sqm area. The vegetable farm includes different eatable species of vegetables like those in the figure below:

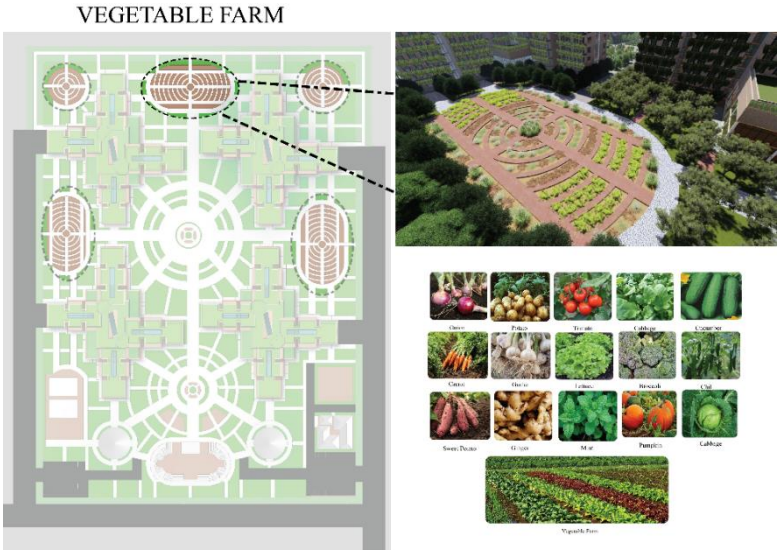

Figure 43: Vegetable Farm

Source: Researcher's own computation

Fruit Farm

The fruit farm houses fruits of varied types that are consumed and taken care of by the community of the site. The total area coverage of the fruit farm is about 2344sqm. Different eatable fruits exist on this farm including the following fruits:

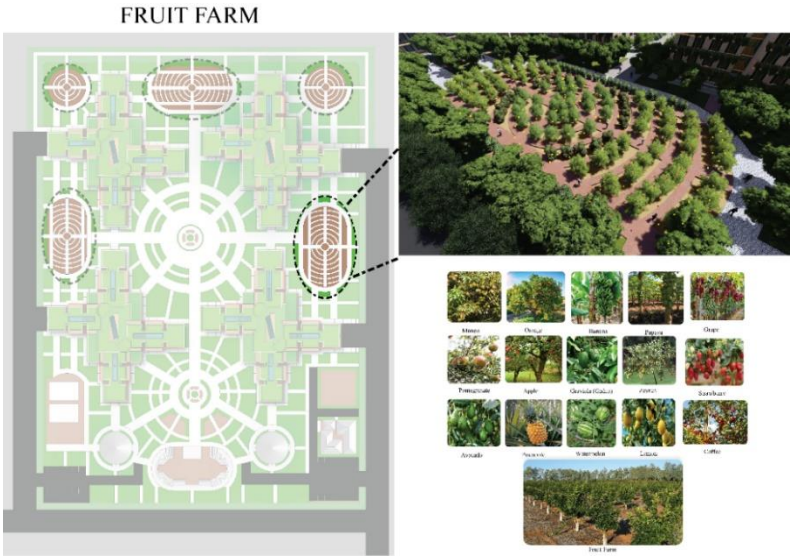

Figure 44: Fruit Farm

Source: Researcher's own computation

Nursery Farm

The nursery farm serves as an area where plant and vegetation seedlings are first grown. This area allows the community to buy plant seedlings and grow them in their homes. The nursery farm lies in an area of about 2005sqm.

Natural Park

The natural park area is located surrounding the site boundaries and acts as a natural buffer for the whole compound. The area is a collection of different species of trees and plants that resembles a natural forest. The community area to access the area through the pedestrians and natural footpaths. The area covers a total of about 9136sqm of land.

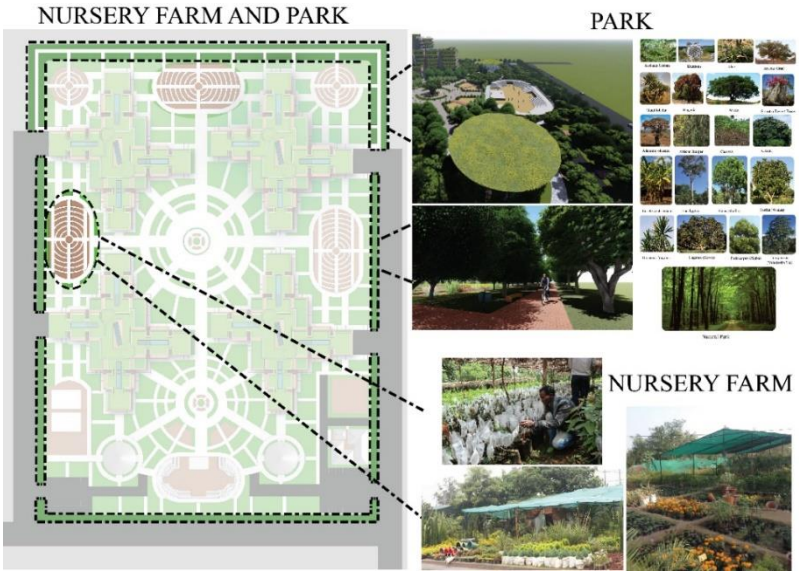

Figure 45: Nursery and Natural Park

Source: Researcher own computation of proposed design

Green House

The Greenhouse can be a place where different vegetation types are planted and accessed by the community. They are areas that can be called the homes of the plants as the plants are given a house to live in. There are two greenhouses each with a total area of 804sqm.

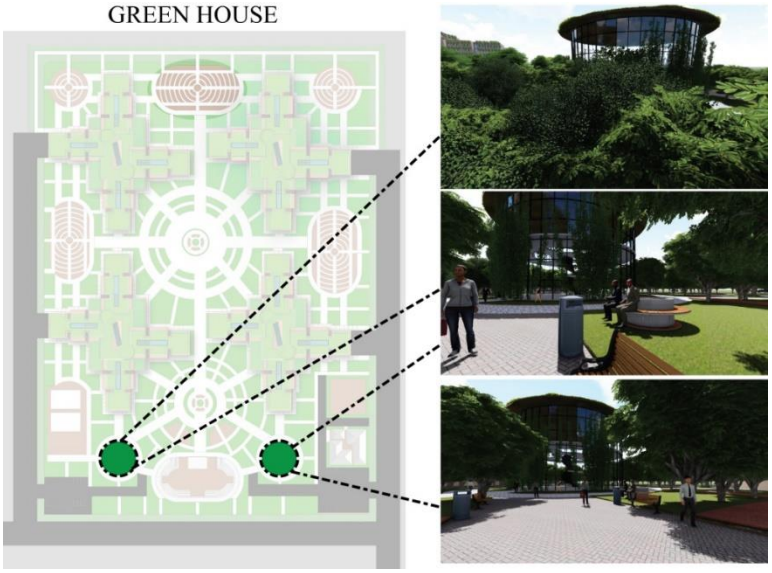

Figure 46: Green House

Source: Researcher's own computation

Community Involvement in Implementation of the Building Greening Systems

The community plays a great role in paving the way for the implementation of these systems as they can be done more simply and domestically which can reduce the cost and maintenance requirement of more advanced systems. Materials such as wood frames, gutters, pots, blocks, water bottles, and so on can be used to plant and grow different vegetation.

Using these materials that are readily available the community can plant different plants and vegetations and place them on their balconies, roofs, inside their homes, on their compounds and so on for different purposes that include beautification such as flowers, consumption such as fruits and vegetables, and recreational purposes such as varied types of trees in open spaces and so on.

Figure 47: Community involvement Building Greening system

Source: Researcher's own computation

Building and Site Integrated Vegetation

Building Greenery						Site Greenery	
Building Typology	Area (m^2)					Types of Greenery on the Site	Area (m^2)
	Greenery Type						
	Green Roof	Green Facade	Green Balcony	Green Terrace	Greenery Indoors		
Building A	3994	3647.76	1164	565	----		
All Four Buildings	3994*4	3647.76*4	1164*4	565*4	----		
Total Area	15,976	14,591.04	4656	2260	----	Site greenery	25,255
Green House	465	330	----	----	433	Natural Park	9136
All Two Green House	465*2	330*2	----	----	433*2	Open Farm Areas	8623
Total Area	930	660	----	----	866	Total Area	44,874
Total Greenery Integrated in The Building			Building + Green House 37,483.04 + 2,456 39,939.04			Total Greenery in the Site	44,874
Total Greenery Integrated in The Building + Total Greenery in the Site 39,939.04 + 44,874 33.28% + 37.39						Total Greenery 84,813.04 70.67 %	

Table 21: Building and Site integrated vegetation

Source: Researcher's own computation

Based on the result obtained from the planning and design of the vertical foresting expansion city in the Dhaka Adi expansion site of the city of Adama it was shown that a significant amount of green and households were provided including services and infrastructures that are defined to be necessities in the providing the system of vertical foresting. The total land coverage of the Dhaka Adi expansion site is about 1324.56 Ha of which 12 Ha was used to design the expansion city plan. In the 12 Ha piece of land four building complexes were placed strategically by which each building held a total built-up area of 7831sqm. The four-building typologies hold a total of 962 households and the total greenery on the site is about 84,813.

12Ha = 962 Households = 84,813 sqm (70.67 %)

Dhaka Adi = 1324.56 Ha= 1324.56 Ha/12 Ha = 110

There are about 110 sites in all the Dhaka Adi sites which means that:

110*926 households = 101,860 households can be provided

110*70.67 % = 7,773.7% greenery can be provided.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Adama city is among the urban centers in Ethiopia that are facing rapid urbanization. The city has been observed to gradually expand and increase both in its population density and its physical range. This research has attempted to study the impacts of the urban expansion of the city on its surrounding green belts mainly on Agricultural land, vegetative land, and bare land through conducted questionnaires, interviews, and LU/LC change analysis over the years of 2000-2021 in four years interval (2000-2007, 2007-2014, and 2014-2021). On the bases of the objectives of the study, the following major conclusions were put forward:

- The data acquired from questionnaires provided to respondents shows that the city has grown and physically expanded to the surrounding area, thus the expansion has shown significant growth of its urban land while agricultural land was highly reduced. On the contrary bare land has also shown an overall increase. The natural vegetation has also shown an increase but the growth is very small and hardly recognizable compared to its counterparts increase i.e., urban land and bare land.
- From the years 2000-2021: Urban land, Agricultural land, and Natural vegetative land have increased from 999.45ha-4823.46ha with a percentage increase of about 7.47%-36.05%, reduced significantly from 9518.13ha-4341.15ha with a percentage of about

71.15%-55.86%, increased from 961.11ha-1284.48ha with a 7.18%-9.60% percent respectively.

- Agricultural land has faced a negative impact through an urban expansion which will affect the general productivity and food security of the city which means there is a need for sustainable agricultural practice in the city to increase the economy.
- Natural vegetation has shown a slight increase which as mentioned above is very low compared to the general growth of the urban built-up area which means there is a significant need to increase and develop this piece of land more to increase and preserve biodiversity, protect land, save from erosions, landslides, and desertification.
- Bare land has shown an initial reduction through the study period but then increased significantly which implies that a lot of lands are being left black and empty. This means land is consumed and a relative amount of it is left bare leaving the land prone to erosion, landslides, flooding, and desertification. To counterbalance these effects there need to be a plan to use these bare lands properly covering them with vegetation and green for the promotion of sustainability.
- To mitigate this problem, environmental protection and sustainable developments need to be implemented to protect and preserve the natural environment. This can be achieved through the integration urban environment with the natural environment. It is also important to reduce the city's footprint on its surrounding by proving basic infrastructures in a smaller area of the city. The urban forest revolution is among the measures taken to integrate the natural environment such as forests with the city.

5.2. Recommendation

Based on the entire research the researcher has put forward a certain recommendation that she believes are powerful measures against the impacts that the existing neighboring environment (Green belts) have faced because of the city's rapid growth.

- Promoting studies and research on the expansion rate and conditions of the city: As shown from the research it is very important to record a city's growth through available resources. There needs to be the proper condition of research to study the city's growth through the regular documentation and examination of the expansion rate of the city by using mechanisms such as Land Use/Land Cover change analysis and proper census of the population to record and follow the cities expansion rate. This will help in knowing the problem first hand and work for solutions by being ready and well informed.

- Rules and regulations should be properly upheld: According to the research the city of Adama has shown and is showing a significant increase in its urban land coverage due to the cities rising urban expansion, thus the areas undergone through the expansion are facing a dramatic change in their existing land use. Surrounding and neighboring green belt areas are constantly being redefined into the urban sector which has caused notable environmental implications; therefore, it is recommended that environmental protection and preservation rules and regulations should be upheld both by the municipality and the community of the city regarding proper land management and environmental protection.
- Community participation and awareness need to be created: Community participation is highly needed to aid the municipality in the accomplishment process of different environmental mitigation actions such as movements such as the Urban Greening Initiatives to work further in creating environmental sustainability. Therefore, the municipality of the city needs to work ardently in creating better awareness in the community to create understanding and integration among each other.
- Exploration of new and innovative ideas will prove helpful: Innovative measures of achieving sustainability should be thoroughly looked into to be a city that is an example to other cities of the country because the city of Adama is a seat for many of the countries conferences and is located strategically linking other cities. Innovation and technologies should be explored to find appropriate methods of implementation.
- A country and its cities need to grow and urbanize in such a way that the growth of natural vegetation, the creation of sustainable agricultural systems, and the proper utilization of barren lands are integrated and interlinked with each other to promote an ever-growing sustainability.

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APPENDIX

APPENDIX I

Research questionnaires for the community of Adama city

Sample no: ----------

Date: -------/-------/--------

The goal of this study is to gather preliminary information on the impact that exists on the surrounding green belt of Adama city due to the city's physical expansion. The benefit of the study is to provide a better understanding of the urbanization trend and physical expansion of the city of Adama and the outcomes of these trends on the environment and how sustainable measures and actions can better mitigate those outcomes. Furthermore, this study will try to provide a better view of the significance of the concept of vertical foresting as a mitigating action and a sustainable choice. Thus, your genuine response is extremely important for the success of the research.

The information requested is purely for academic purposes in which you are kindly required to feel free and respond to all the questions as honestly and confidentially as possible. Thank you in advance for your cooperation.

Meseret Tesfaye

MSc candidate in Urban Planning and Design

Vertical foresting:

Vertical foresting is a new and innovative concept that works in creating cities by integrating them with nature to create a sustainable living environment in which buildings are built with nature. This system helps the buildings give back to nature what they had taken from it for their construction. Common examples that can be used to create these systems are i.e., using plants as shades by planting them on balconies, using them as green gardens, as roof gardens and as facades for the buildings, and so on. This system is one of the ways today's world is used to achieve sustainability. Sustainability is a general term that describes the state of being able to meet the needs of the present society without compromising the needs of the future society in terms of resource allocation.

General information

Please put √ in the appropriate box/ boxes for your answer

1. Sex

    1. Male ☐
    2. Female ☐

2. Please mark your age group in the appropriate box

    1. 15-19 ☐
    2. 20-24 ☐
    3. 25-29 ☐
    4. 30-34 ☐
    5. 35-39 ☐
    6. 40-44 ☐
    7. 45-49 ☐
    8. 50-54 ☐
    9. 55-59 ☐
    10. 60 and over ☐

3. What is your educational status?

    1. Not educated ☐
    2. Primary/ lower school ☐
    3. High school ☐
    4. Diploma ☐
    5. Bachelor Degree ☐
    6. Masters ☐
    7. PhD/ above ☐

4. How long have you been living in Adama city?

    1. 1 year and below ☐
    2. 2-7 years ☐
    3. 8-13 years ☐
    4. 14-19 years ☐
    5. 20 years and above ☐

5. Do you think that Adama city has grown?

    1. Yes ☐
    2. No ☐

6. If your answer is 'Yes' to question number '5', for what reason do you think Adama city has grown?

    _____

    _____

7. Do you believe Adama city has physically expanded?

    1. Yes ☐
    2. No ☐

8. If your answer is 'Yes' to question number '7' for what reason do you think Adama city has physically expanded?

    1. Housing/residential ☐
    2. Transportation and road ☐
    3. Industry ☐
    4. Commercial and Business ☐
    5. Market and Investment ☐
    6. Other:

    _____

9. Would you please try to elaborate on your answer to question number '8'?

_____

_____

_____

10. Do you believe the physical expansion of Adama city caused negative impacts on the surrounding Green Belt area of the city?

    1. Yes ☐
    2. No ☐

11. If your answer is 'Yes' for question number '10', on which parts of the surrounding green belt areas did the negative impact occur?

    1. Agricultural/Farmland ☐
    2. Bare land/ Open spaces ☐
    3. Natural vegetative land/ Forests, Grasslands, shrubs ☐
    4. Other:

    _____

12. Would you please try to elaborate on your answer to question number '11'?

_____

_____

_____

13. What do you think the term vertical foresting and its concept means?

_____

_____

_____

14. Do you believe the system of vertical foresting can mitigate the impacts that have occurred on the surrounding green belts of the city of Adama?

    _____

    _____

    _____

Thank you

APPENDIX II

Interview for Adama city Governmental organizations and government officials

Date: -------/-------/--------

The goal of this study is to gather preliminary information on the impact that exists on the surrounding green belt of Adama city due to the city's physical expansion to promote a better understanding of the significance of the concept of vertical foresting as the mitigating action and a sustainable choice.

Meseret Tesfaye

MSc candidate in Urban Planning and Design

1. How do you understand the physical expansion of Adama city and its impact on the surrounding environment of the city particularly on the existed green belt?
2. What solutions the city administration is working on to mitigate the physical expansion of the city.
3. What solutions the city administration is working on to mitigate the affected parts of the environment specifically the existed green belt surrounding the city.
4. Are there existing rules and regulations regarding environmental protection, preservation, and implementation strategies in collaboration with sustainability issues for the city?
5. Explain your views and experience of the city regarding sustainability attainment through vertical foresting.

Thank you!

Figure 48: Site Observation Images

Source: Researcher's own survey

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