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Ethiopian Institute of Architecture Building Construction and City  
Development (EiABC)

## Prospects of Green Roofs Applications in Alleviating Environmental Challenges & improving GI of Addis Ababa

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Masters of Science in Landscape Architecture.

Prospects of Green Roofs Applications in Alleviating Environmental  
Challenges & improving GI of Addis Ababa

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## **Declaration**

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all source of material used for the thesis has been duly acknowledged.

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## **Confirmation**

This thesis can be submitted for examination with my approval as a university advisor.

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## Acronyms

<b>GR</b>	Green roof
<b>RG</b>	Roof Garden
<b>GI</b>	Green infrastructure
<b>UGI</b>	Urban Green Infrastructure
<b>E.N.U.G.I.S</b>	The Ethiopia National Urban Green Infrastructure standard
<b>MUDHo</b>	The Ethiopian National Urban Green Infrastructure standard, Ministry of Urban Development and Housing
<b>HOAREC</b>	Horn of Africa Regional Environment Center
<b>GSA</b>	United States General Services Administration
<b>ABBA</b>	ABBA Architects. Plc.
<b>EiABC</b>	Ethiopian Institute of Architecture Building Construction and City Development
<b>UNESCO</b>	United Nations Educational, Scientific and Cultural Organization
<b>RC</b>	Reinforced Concrete

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## Abstract

Alternative green infrastructure solutions such as green roofs and green exteriors offer a better coping mechanism for the loss of the conventional green space in the built environment. It also offers various ecosystem benefits & bionetwork services, particularly in cities where there is an absence or lack of conventional green spaces due to several factors. To mention some of the benefits: improved food security, better storm-water management, improved aesthetics, efficient control of building temperatures, reduced urban heat-island effects, improved mental health in society and increased urban wildlife habitat.

On top of exploring these extensive benefits, this research investigates the major difficulties and constraints that hinder the widespread application of alternative coping mechanisms specifically green roofs in the case of Addis Ababa. Considering the huge and prominent potential of green roofs offer to retrieve the lost green elements and spaces; and their respective services, the research asking why such alternatives are not well adapted in the city scale. In this regard, this research has explored evidence in applications of green roofs in the respective context and challenges as well as benefits for the city by examining the current trends of their applications. To carry out these investigations; the deployed methodologies are case study method, observations as well as conducting in-depth interviews together with an extensive literature review.

The findings of the study confirm the extensive use of green roofs in the context of Addis Ababa for compensating the lost conventional open spaces and their multiple benefits. Moreover, the interrelated challenges in the application of the system about the absence of regulations, limited skill in design and construction, and minimal awareness of its co-benefits are identified. Accordingly, adaptable, flexible and cost-effective design recommendations are forwarded in order to alleviate the identified challenges and to contribute for sustainable growth of the city. Moreover, the research recommends further investigations on the extensive adaptation of green-roofs and other similar green infrastructure solutions to explore and deploy their potential in future urban design and planning practices in Addis Ababa. Moreover, the city administration can adopt as a guideline for the development of a green infrastructure system in day to day building and landscape development practices.

# Chapter – 1

## 1.1 Background

One of the characteristics of a healthy city structure and system remains to be the existence of a balanced green infrastructure network that is well integrated with the built urban fabric. On the other hand, city developments in third world countries usually do not consider the green network aspect in the same way as the development of the hardscape (Building infrastructures). In the long run, this leads to the disappearance of critical green elements throughout the city's urban fabric. It is essential to understand what is vanished in that development. Above and beyond to their aesthetic value, urban green elements enhance various natural city systems such as to infiltrate rainwater easily, offer a decent temperature regulation system, being a habitat for a variety of species, adjust air and water quality. The conventional urban fabric now days have tiny permeable surfaces, so metropolises lacking this natural process will be easily affected by various problems like flooding, water pollution and increased temperatures through the urban heat island effect (GSA, 2011).

Green roofs have been around for greater than 100 years, and they developed to one of the important components in cities for the past few years. Several scientific examiners focus on its temperature regulation performance, efficiency and survival rates of plants (C & K., 2014). Moreover, green roofs can assist in minimizing the complications that cities produce by bringing the natural temperature regulating, water management and air filtration assets that vegetated landscapes offer to the cities. “Architects and planners can use green roofs to solve environmental problems by bringing nature back to the city in key ways. Green roofs, if properly designed, constructed and maintained, are beneficial socially, environmentally and fiscally. It is an important tool to increase sustainability and biodiversity and decrease energy consumption, urban heat island impacts and greenhouse gas generation” (GSA, 2011)

Green roofs can benefit cities within a similar condition like Addis Ababa that are experiencing loss of green spaces and their ecosystem services. In Addis Ababa, this has been noted majorly in the past 15 years as a substantial alteration in the general ecosystem. As clearly analyzed and stated in T. Matias, 2016, “shrinking of urban green spaces in Addis Ababa: plantations, forestland, grassland and cultivated land (at annual rates of 5.9%, 3.3%, 5.4% and 3.7 % respectively) by 82.1%, 62.1%, 78.8 and 65.8 % respectively during the past three decades (1986-2015) whereas built-up and transport areas increased at annual rate of 5.7% and 1.3% and consumed 419% and 47% of the city's total area respectively.”

Researches indicate that Addis Ababa is one of the cities that experiencing loss of green spaces and their ecosystem services. Moreover, this shows that the extent of natural and permeable land cover change which is reflected in the city by the alleviated urban heat island effect results in increased building temperatures, loss of biodiversity, increased stormwater runoffs, social problems linked with the loss of appropriate green spaces, etc.

In order to address such challenges, cities try to maximize their public spaces in providing public parks and conventional gardens, etc. However such conventional green area provision approaches, for instance, public parks, allotment gardens & conventional street greeneries allocation in the existing set up of many cities including Addis Ababa is not working up to now because of mainly unprecedented urbanization. Hence the need for instant and easy to integrate the solution within the already built urban environment can be an invaluable option. Such options include alternative green network approaches that are needed as a substitute system. When one comes to this alternative green infrastructure solutions, one must also first consider special systems that can be easily adaptable and can make a huge impact on the cities fabric.

The main world widely accepted successful alternatives for green infrastructure solutions are primarily green roofs and green walls. Since several types of research and experiments are conducted on green walls by various organizations in Addis Ababa including in EiABC, the need for the research and adaptation means of the green roof system found to be relevant. Regardless of its huge potential, substantial contextualized studies have not been conducted so far. Hence, the exploration of contextual benefit with its practical, adaptable and cost-effective application is the focus of this research.

## 1.2 Problem Statement

A report by UN-Habitat shows that “climate change is challenging urban areas due to loss of Green Infrastructure by the development that takes place in cities”. Commonly the degradation of cities Green Infrastructures in third world countries inversely interconnected to city growth. In the meantime when there is unbalanced growth in urbanization, cities green infrastructures decline in scale and several urban problems escalate, gradually this creates numerous challenges on the city inhabitants (Berhe, 2015).

Addis Ababa is the political capital city of both Ethiopia and Africa, where several of worldwide diplomats & international organizations reside. In addition to this, the city is transforming rapidly while also expected to accommodate a population closer to 4 million in total in the coming years ([www.worldpopulationreview.com](http://www.worldpopulationreview.com)). However, experiencing the development of unbalanced urban fabric that neglects the environment and other urban ecosystem dimensions which have created various inappropriately planned and constructed new and old hard infrastructures are a threat to healthy living in the city. The challenges fronting complicated resulting with environmental & socio-economic difficulties are also associated with deficiency of appropriate green infrastructure elements, administration, and protection. Most of all, the lack of appropriate green infrastructure in the city itself is not recognized and researched (*Samson A.2014*).

Recently Addis Ababa is growing rapidly both horizontally and vertically. Particularly in the past 15 years, the city has experienced large scale development of various types of settlements, both in formal and in informal sectors. This includes streets with varying size and expressways, sports fields with paved surfaces. On the other hand, green patches, parks, green street medians, permeable surfaces, and overall green coverage are continuously decreasing.

This type of unbalanced city growth generated and altered the city's natural ecosystem balance. In the meantime, it also affects the overall natural environment and creating a problem on the city residents. These problems include as stormwater runoff problem, various social problems, rapidly increasing the temperature around the buildings and other parts of the city, green vegetation network disintegration, loss of biodiversity, river pollution and urban food security problems.

Consequently, the impact of the stated challenges resulted in warm seasons with associated health and economic crises. So far there are no significant & comparable measures taken at city scale as alternative coping mechanisms. However, the majority of the developed countries are considering various coping mechanisms to create environmental resilient cities worldwide.

Currently, there are very few attempts by developers and government on integrating alternative green infrastructure solutions such as green roofs and other green building solutions. In respect to their enormous and prominent potential as an alternative solution for solving various complicated environmental and socio-economic problems, one can say that such alternatives are almost not explored and not utilized to their full potential in Addis Ababa. The absence of sufficient green surfaces is a prominent problem that needs an urgent solution to reduce the environmental problems that are mentioned above.

This research paper explores and studies the major difficulties, challenges, and constraints that hinder the widespread city scale adaptation of green roofs and roof gardens in Addis Ababa. At that moment, it will try to show the prospects of adaptive mechanisms to alleviate the existing barriers so that to easily catalyze and expand the applications of alternative green infrastructures specifically green roofs at city scale.

## **1.3 Objective**

### **1.3.1 General Objective**

To develop a design guideline as a deploying mechanism intended for the application of a localized solution at rooftops as an alternative coping mechanism for the loss of green patches, at the same time compensating the respective lost in ecosystem services in the rapidly growing developing-cities like Addis Ababa.

### **1.3.2 Specific Objective**

- To assess the existing green roofs development challenges in Addis Ababa.
- To come up with contextual and customized green roof designs & guidelines, through developing prototype designs

## 1.4 Research Questions

### 1.4.1 General Research Question

What the appropriate alternative GI solutions could be contextually relevant for alleviating social, economic and environmental impacts of losing green patches in rapidly growing cities like Addis Ababa?

### 1.4.2 Specific Research Questions

1 Why the advantageous green roof systems that have a huge potential that can be used as an alternative mechanism to cope with urban green loss were not adapted in extensive scale on the urban fabric of Addis Ababa?

2 How can it be contextualized and adopted at the city scale?

## 1.5. Scope

In terms of scale, the scope of the research is city scale having purposively selected buildings as a unit of analysis or cases.

In terms of content: the research highlights on GI solutions but focuses on green roofs as they are found relevant due to the lack of comprehensive and substantial study's on this specific area due to the lack of attention undermining its huge potential to offer to Addis Ababa.

Correspondingly as an application area, most as the solutions focus on a prototype solution that can be adaptable at the city scale (which is Addis Ababa). However, since most of the localization technics will work in similar secondary cities, it will address national level extent concerning the effective applications of alternative green infrastructure solutions.

## 1.6. Significance

As the result of successful adaptation of alternative green infrastructure solutions, the lost green patches in Addis Ababa and the lost ecosystem services respectively will be highly compensated. This research eventually will support the current building and landscape construction systems for a green roof for various types of buildings in the city. For scientific researchers, it can help for future assessments and researches that are mainly concerned with developing green roofs on extensive scale in the city. It also helps policymakers and the municipality so that, they can utilize it for the guidance for general green roof design and construction regulation.

## 1.7 Overview of problem analysis

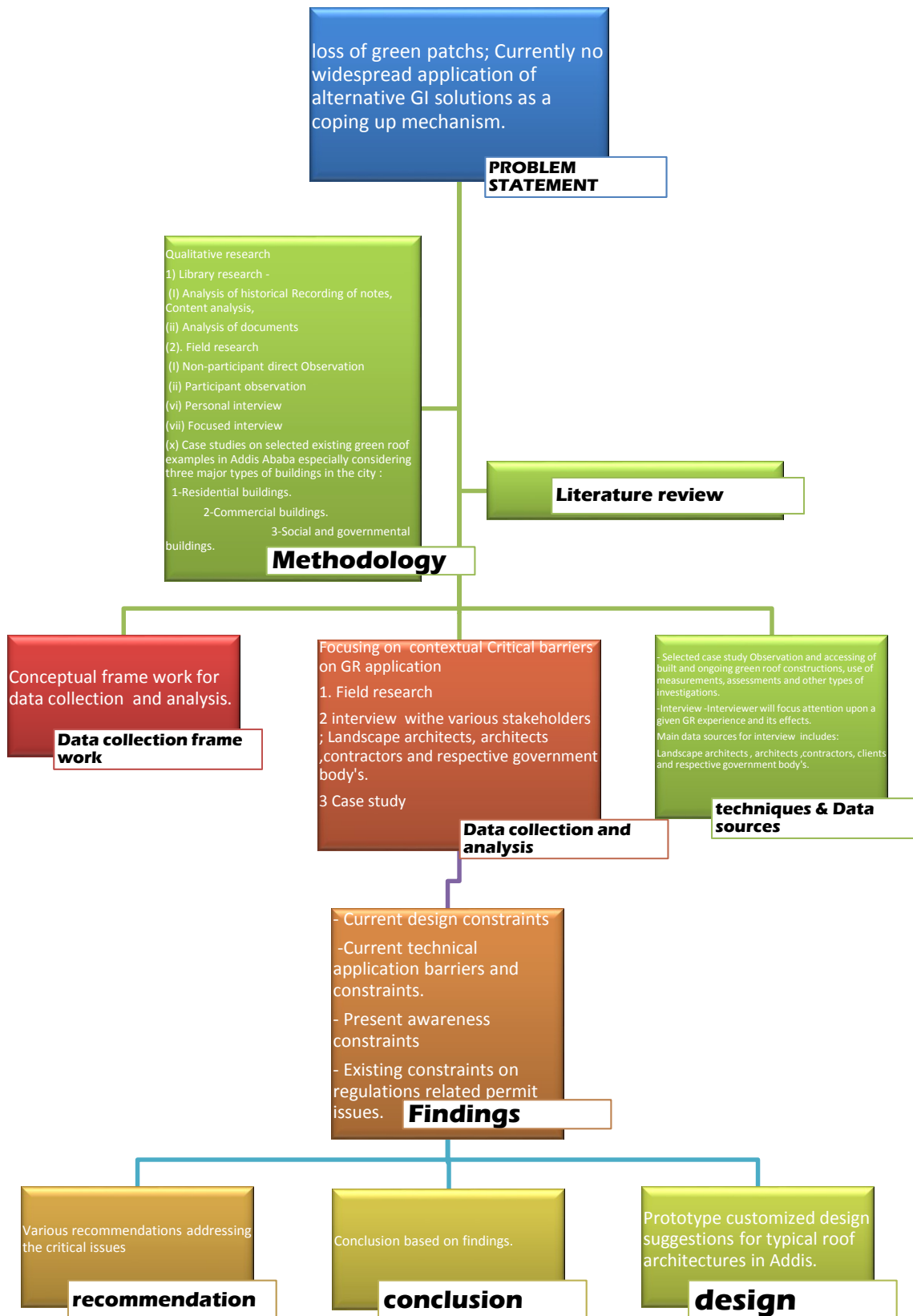
Cause, outcome and impact matrix

Cause	Out-come 1	Out-come 2	Impact
Not well thought and rapid urbanization with formal and informal development neglecting the green infrastructure aspect.	<ul style="list-style-type: none"> <li>-The weakening and the decline of green elements in the urban fabric of Addis especially within the emerging and existing vertically densified parts.</li> <li>-Loss of productive urban green landscape that promotes sustainable urban agriculture.</li> <li>- The degeneration various ecosystem services</li> </ul>	<ul style="list-style-type: none"> <li>- Environmental problems such as the decline and absence of carbon sequestering green elements within the densified parts.</li> <li>- The weakening and decline of urban biodiversity.</li> <li>-The degeneration of available open green space for various socio-economical purposes within the built fabric.</li> <li>- The increasing of non-permeable surfaces that can't support rainwater infiltration.</li> </ul>	<ul style="list-style-type: none"> <li>• The rising building temperature (impact on comfort in buildings and Building Energy Efficiency)</li> <li>• The concentration of carbon dioxide, because the loss of green patches taking the co2 (loss of Carbon sequestration)</li> <li>• Risks of Stormwater runoff and Flood during the rainy season.</li> <li>• Urban Dirt and dust.</li> <li>• Urban Heat Islands effect.</li> <li>- Impact on social health such as mental health respiratory etc... because of the absence of recreational green landscapes.</li> <li>- Impact on macro-level temperature rise.</li> <li>- Aesthetical impacts in the urban fabric</li> <li>Other economic, spatial impacts</li> </ul>

## 1.8 Consistency Matrix

PROBLEM statement	Research questions	Research objectives	Research methodologies	Techniques & Data sources
<p><i>Sub-problem:</i></p> <ol style="list-style-type: none"> <li>There is an increasing loss of urban green patches and elements in the densified parts of Addis Ababa, creating a deteriorating ecosystem services, however there is no successful alternative coping up mechanisms are adapted as means for the weakening urban green infrastructures.</li> <li>Particularly the ingenious &amp; the advantageous alternative urban green space solutions such as green roofs &amp; green exteriors are not well adopted on extensive scale in Addis Ababa to alleviate the micro and macro level environmental and socio economic challenges.</li> </ol>	<ol style="list-style-type: none"> <li>Why the advantageous green roof systems that have a huge potential that can be used as an alternative mechanisms to cope urban green loss were not adapted in extensive scale on the urban fabric of Addis Ababa?</li> <li>How can it be contextualized and adopted at city scale?</li> </ol>	<ol style="list-style-type: none"> <li>To assess the existing green roofs development challenges in Addis Ababa.</li> <li>To come up with contextual and customized green roof designs &amp; guidelines, through developing prototype designs</li> </ol>	<p><b>Methodology 1 (For specific research question 1)</b></p> <ol style="list-style-type: none"> <li>Library research on green roofs notes, publications and content analysis on green roof systems.</li> <li>Analysis of local guidelines</li> </ol> <p><b>(2). Contextual study (Case study assessment)</b></p> <p>Conducting investigation on selected green roofs case study's as a tool for obtaining the needed information to address the research questions.</p> <ol style="list-style-type: none"> <li>Non-participant direct observation</li> <li>Recording of existing situation using various Medias</li> </ol> <p><b>(3) In depth interview with respective stakeholders.</b></p> <p><b>3.3 Methodology 2 (For specific research question 2)</b></p> <ol style="list-style-type: none"> <li>Study on international sources for innovative GR products.</li> <li>Study of various publications and related contents</li> <li>Study of Modular GR designs</li> </ol> <p>Conducting investigation on successful international modular GR system as case study's to obtaining the road map for customization.</p> <ol style="list-style-type: none"> <li>Local available materials investigation for the use of modular green roofs.</li> </ol> <p>To understand the context using local market assessment as well as using in-depth interview.</p>	<ol style="list-style-type: none"> <li>Observation and accessing of built and ongoing green roof constructions, use of measurements, assessments and other types of investigations. <ul style="list-style-type: none"> <li>Inter-actional recording, possible use of tape recorders, photographic media ,use of audio-visual recording devices and other similar devices.</li> </ul> </li> <li><b>Interview</b> <ul style="list-style-type: none"> <li>Interviewer will focus attention upon a given experience and its effects. Such as : <ol style="list-style-type: none"> <li>Interview with landscape &amp; building architects and also contractors on previous green roof/roof garden projects constraints and success.</li> <li>Interview with – respective governmental authority's stake holders related to the guideline and enforcement issues.</li> </ol> </li> <li>Interviewer will use a detailed schedule with open and closed questions.</li> </ul> </li> </ol>

## 1.9 Research Design



## **1.10 Limitation**

This research has a limitation of time and money. Concerning the research fund, there is no budget given by the University to work on this investigation as a same time to employ manpower to examine the study area. Since the study is highly based on the ground data, concerning time, the study area is huge and it is hard to investigate all of the study areas with the given little time.

## **1.11 Structure of the document**

This research paper is structured into five main chapters. The first chapter, in the beginning, contains the background of the study, statement of the problem, the objective of the study, research questions, limitations, scope, significance, research structure, and research design. After that chapter two will - mainly discuss -literature review on green roofs both international and local literature. Chapter three comprises the general research methodology, techniques, sources, and procedures. Chapter four covers mainly research findings, contextual review, and analysis. Finally, the last chapter which is chapter five concisely give summaries, conclusions, and recommendations respectively.

# Chapter 2. Literature review

This research paper will try to examine literature from various research papers and documents, especially focusing on alternative green infrastructure solutions and on general green roof and roof garden systems.

Chapter two is mainly focused on the introduction to the major types of green roofs and roof gardens. Then, it follows by describing why green roof application on the existing built urban fabric is the best solution as coping up mechanism for the lost conventional ground level green elements in the urban fabric of Addis Ababa. After that, it will continue to study the major environmental, social and economic benefits of green roofs that makes them a better alternative solution on densified urban areas.

Next, it tries to define what roof gardens/green roofs are and what major types of green roofs are there. Afterwards the definition, it proceeds by exploring the question of major constraints and limitations that hinder the broad and widespread applications of such types of green infrastructures in developing urban parts. Later it precedes by a Contextual review (Local guidelines review).

## 2.1 Introduction

Addis Ababa is now loosing most its conventional green patches such as public gardens/parks communal recreational fields, urban forests, urban agriculture, and other conventional green infrastructures and the respective benefits that's comes from such types of greens. Major ecosystem losses include -

- Building temperature regulation (Cooling and Building Energy Efficiency)
- Absence of green plants that contribute to Carbon sequestration
- Stormwater runoff & flood during the rainy season because of the lack of permeable surface that infiltrates water
- Increasing Urban Dirt and Dust
- Loss of Urban Biodiversity and Habitat
- Lack of Air quality mainly in the densified parts
- Increased Urban Heat Islands effect
- Lack of urban food production due to the absence of production area
- Aesthetics and quality of life issue due to the absence of .healing green elements on the urban fabric
- Increased sound pollution (outdoor-indoor acoustics Issues.)

- Increasing in temperature recent times and its impact on energy conservation on buildings

### 2.1.1 Green Infrastructures

#### Definition

There are as various descriptions of a green infrastructure internationally. For this research three main definitions are taken as a general framework. Benedict and McMahon's study (as cited in Aynachew, 2014) defines green infrastructures as “interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas: greenways, parks, and other conservation lands, working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for communities and people.”

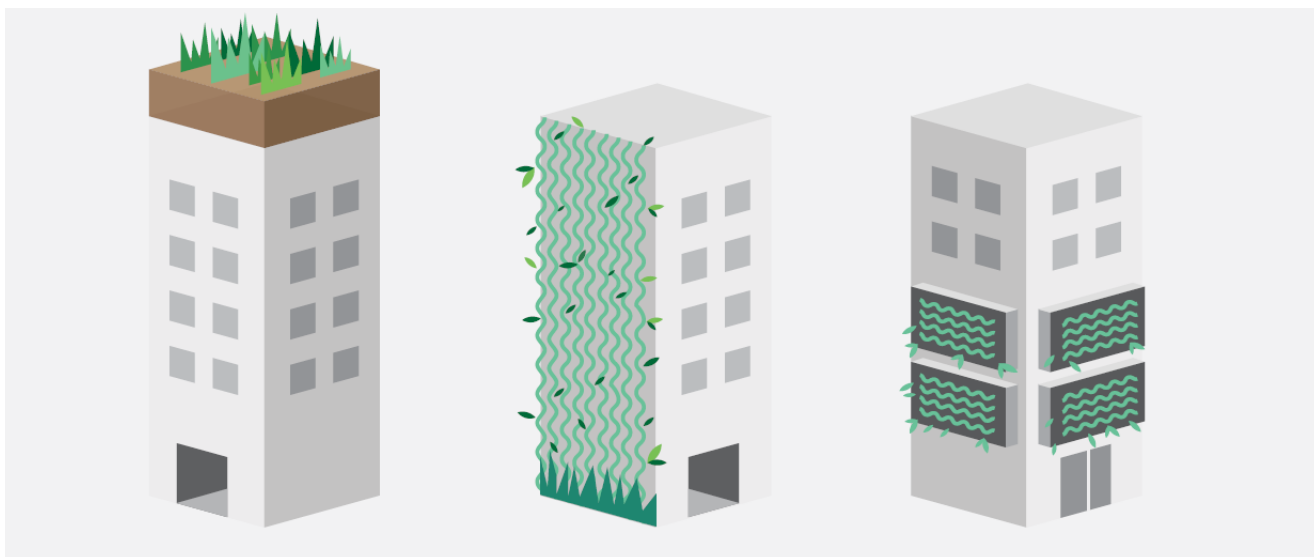
Another interesting definition by Williamson (as cited in Aynachew, 2014) states that “green infrastructure means that our nations natural life support system-an interconnected network of protected land and water that support native species, maintains natural ecological processes, sustains air and water resources and contributes to the health and quality of life for America’s communities and people.” The third definition is by Davies (as cited in Aynachew, 2014) describes green infrastructures as “as part of an urban area with a mix of street trees, parks, cultivated land, wetlands, lakes, and streams.”

When we condense from the above green infrastructures definitions, green infrastructures consists of a very prominent natural urban elements of a city that give life and enable it to function in a natural and sustainable way. In the absence of even the smallest of these elements creates a loophole that is unsafe in alternating the natural living cycle of community’s and as well as the overall urban ecosystem.

#### Possible lists of green infrastructures

- Urban forests
- Urban parks
- Wetlands
- Green exteriors
- Green allies
- Green schoolyards
- Natural reserves
- Channeled rivers
- Suburban gardens
- Urban botanical gardens
- Streetside greens

- lakes
- Urban framings
- Zoological gardens
- River buffer vegetation networks
- streams



*Figure 1 major types of green exteriors in a building. Source: (State of Victoria, 2014)*

Green roofs are found in the subsection of green exteriors. Green exteriors mainly consist of green roofs, green wall/facades, and other similar green building elements. Due to various challenges and factors that are responsible for certain the situation of unbalanced city planning, the conventional green infrastructures which are mentioned above become relatively disappeared and lost in the current situation of Addis. Several types of research and studies had been conducted by Addis Ababa University and other institutions in this area. To mention one, a research by Tebarek & Mathias, 2016 entitled “*The city of Addis Ababa from ‘forest city’ to ‘urban heat island’: assessment of urban green space dynamics*” can be a good example from various types of research aiming to alleviate the factors that are responsible for the disappearances of the conventional green patches, however, there is no evident result had been achieved to heal the city in a conventional approach.

As a result of the above reason, alternative, unconventional green infrastructure solutions can be used as an alternative means to regain the lost conventional green infrastructures, as well as their respective services. One of the prominent alternatives is a green building approach, which mainly consists of green roofs and green walls as green skin for the overall city fabric.



Figure 2 Addis Ababa skyline photo source: Samson E.

### 2.1.2 Why green exteriors are a better alternative as a tool to retrieve the lost green patches benefits on the urban fabric of Addis Ababa?

Having the above-mentioned issues, currently there is a critical urgency for the need of alternative coping mechanisms to tackle these concerns. The alternative green infrastructure approaches are preferred since there is a little attention given to regain the conventional green patches using the straightforward way by government, and the overall construction industry. This is a result of various factors including, the lack of awareness and the understanding of a healthy & holistically developed urban fabric system in the current situation of Addis Ababa. Main issues include, the absence of awareness for the need of a proper scale green patches at residential and commercial buildings level. This creates a situation where all the available plot of land is highly utilized for construction of structures only. This problem is also connected with the issue that, city level land administration failed to effectively manage and create an appropriate size of green spaces in city centers. The utilization of the existing rooftop surfaces is a plus for the potential remediation of green patches in the highly densified urban fabric of Addis Ababa.

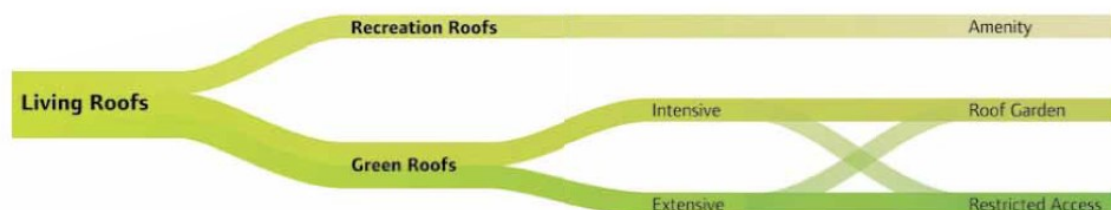


Figure 3 Green roof classifications image source (Duda, 2009)

## 2.2 What are green roofs and how do they work?

### 2.2.1 Definition

Green roofs are vegetated roof surfaces consisting of waterproofed roofing systems, soil, and plants. Generally, there are two major kinds of green roofs. Extensive green roofs have a thin soil section having a soil thickness reaching 10 to 25 cm, and are vegetated mainly with moist and succulent plant species to make the most of the environmental benefits. Intensive green roofs are complex, and have a thicker soil layer or section reaching from 30 cm to even a few meters. Green vegetation cover or the landscape above structure are proposed for dynamic use and re-forming and to display a more extensive, natural scale and also established landscapes. Vegetation's on extensive green roofs even can contain shrubs and trees (UN, 2010).

Cautious structural design is mandatory to confirm the load-bearing abilities of the structure. This is the study of the sufficiency of the structure to support the load of the soil, vegetations and other green roof elements. For example, if a green roof is needed to be accessible for various types of purposes, the green roof section load has to be considered into the structural ability. When it is viewed from a structural dimension, green roofs and roof gardens adds a minimal cost to new buildings overall cost. Though applying to the already built building may need structural modification, sometimes this can be expensive. Though most extensive green roofs can be applied to existing buildings with a little or no structural modification for most developing country's cities like Addis Ababa. In most dry weathers extensive and intensive green roof types shall be irrigated for vegetation's to stay alive. Water management and reduction can be achieved by selecting succulent plants and by watering with collected rainwater. Sustainability should be highly prioritized in the overall design process of green roofs (UN, 2010).

### 2.2.2. Types of Roof gardens and Green roofs.

Before classification of the different types of green roofs, we must understand the composition and intensiveness of various layers of materials and vegetation's composing that specific green roof.

The G.S.A study discuss this well by classifying that all green roofs in to two key categories. The first one is, the “**extensive green roof**” that is comparatively low-cost to construct and usually intended for various environmental benefits (microclimate control, urban biodiversity and habitat, stormwater management etc...). The second one is the “**intensive green roof**”, they have good potential to habituate a better diversity of plants, including various types and sizes of trees, and shrubs. These types of green roofs (intensive green roofs) are comparatively costly to construct and preserve. This is as result of for the need for substantial irrigation and maintenance cost. Green roofs that are found on most commercial and public buildings usually constructed using the extensive green roofs approach. But there are some exceptional cases that green roofs can be intensive if it is necessarily needed for human accessibility.

	SINGLE-COURSE EXTENSIVE	MULTI-COURSE EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
THICKNESS	3-4 inches	4-6 inches <sup>(a)</sup>	6-12 inches <sup>(b)</sup>	over 12 inches
DRAINAGE LAYER	No discrete drainage layer.	Based on the growth media thickness, plants selected, local climactic conditions, and rooftop hydrologic conditions. Synthetic geocomposite are typical nationally. <sup>(d)</sup>	Discrete drainage layer.	Discrete drainage layer.
VEGETATION LAYER	Sedum or other succulents.	Sedum or other succulents. Potential for other plants as thickness increases or with permanent irrigation.	In the Mid-Atlantic and with irrigation, supports a variety of plants—meadow species, ornamental varieties, woody perennials, & turf grass.	Supports plant communities similar to ground-level landscapes (depending on thickness and exposure).
MEDIA TYPE	Coarse media over moisture-management layer.	Finer-grained growth media over discrete drainage layer.	Multi-course over discrete drainage layer.	Intensive growth media layer over discrete drainage layer. Topping media may be used (includes higher organic content, greater density, greater water holding capacity, and lower permeability).
IRRIGATION	Typically none.	Typically necessary in the first year to establish growth in Mid-Atlantic.	Required if turf grass is used.	Required.
PREVALENCE	Common internationally. Areas with sufficient precipitation is necessary.	Nationally the most common green roof type.	Common. Provides more variety in vegetation.	Less common than the other types. Structural capacity and maintenance are limiting factors (see Section 4.4.1 and 4.3)

Figure 4 the four major types of green roofs. Table source (GSA, 2011)

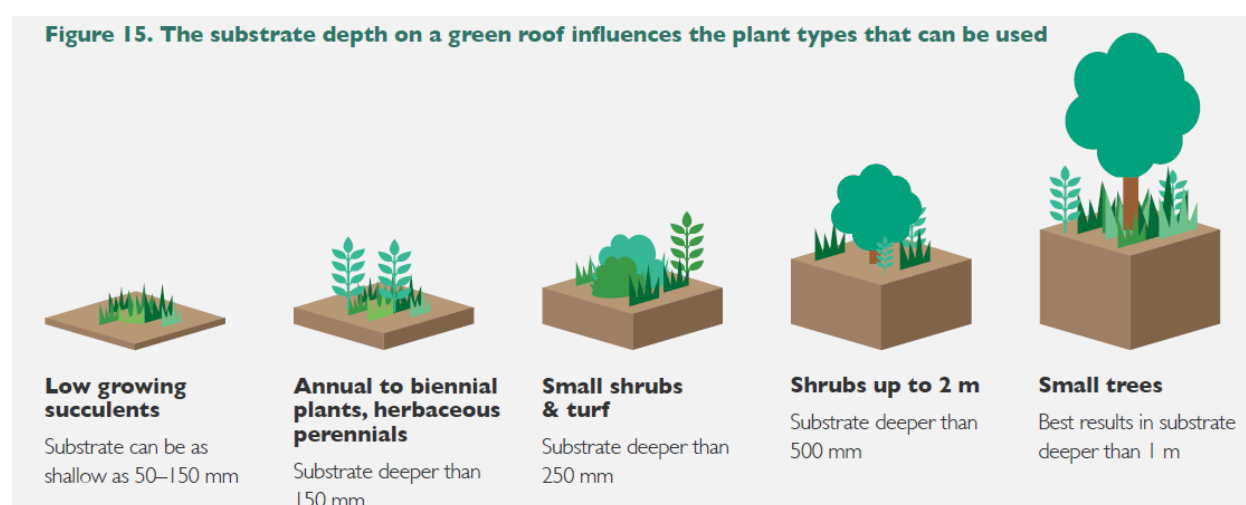


Figure 5 Several levels of the substrate layers, and the types of plants. Image source: (State of Victoria, 2014)

### 2.2.3 Extensive green roofs

Extensive green roofs consist a thin soil or substrate layer, and can have moist/succulent vegetation's, including sedums that have a capability to stay alive in hot and dry weather conditions. Extensive green roofs need very low preservation/ maintenance in their lifetime. Most of the extensive green roofs are commonly economical and predominantly have extended lifetime durations without close maintenance (GSA, 2011).

### 2.2.4. Intensive green roofs

Most of the intensive green roofs consist of, denser/heavier and thick soil cover that can be vegetated and landscaped with various plant types that can replicate the conventional ground-level urban parks and botanical gardens. Such types of plants need watering/irrigation throughout the harsh hot and dry seasons (typically in summer). For a reason that of the nature of the layer composition of their dense and thick substrate layer, most type's intensive green roofs need stronger roof structure compared to extensive green roofs. On the other hand-intensive green roofs give additional uses such as, more human accessibility for recreational and other needs and for various environmental advantages in the urban area (GSA, 2011).

### 2.2.5 Subclassifications

To look furthermore, there are four subtypes of green roofs sub classifications (when they are classified in explicit and detail according to the substrate, material makeup and vegetation intensiveness).

- **Single-course**
- **Multi-course extensive**
- **Semi-intensive**
- **Intensive**

Mainly this four types of green roofs differ by the nature of the vegetation that is planted, the necessity for watering/irrigation, the category of drainage system used to channel extra storm or irrigation water, and the configuration of the general growing material, which is the soil or another substrate.

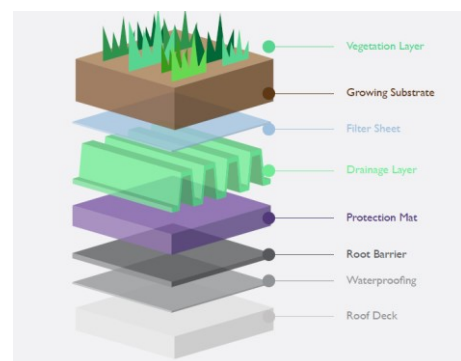


Figure 6 several layers of a green roof, Source: (State of Victoria, 2014)

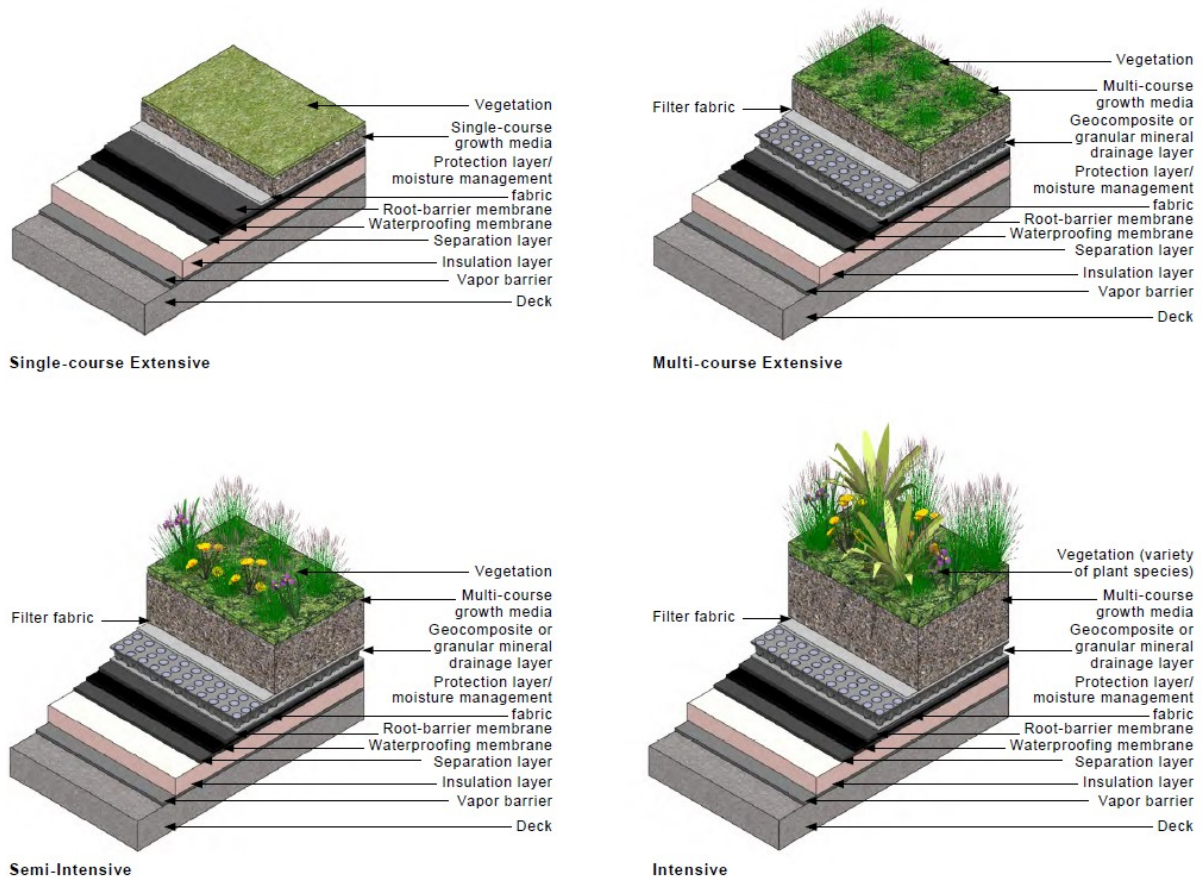


Figure 7 image showing various course level of green roofs Image source (GSA, 2011)

## 2.2.6 Other types "Modular green roofs"

Furthermore, differing from the conventional green roofs that are mentioned above, there are alternative green roof types which are called "modular green roofs". These types of green roofs usually made up with various depths and sizes of modules to create numerous types of green roof systems.

Modular type green roofs are constructed by combining a modular planters/trays, having the substrate (growing media, including soil and other materials) and plants. This trays can be transported to the structure and mounted instantly. Modular green roofs can be offered in a variety of complexities and depths, and they are an easy economical and direct method to install a green roof layer. Modular green roofs can be easily widespread, this is for the reason that, they give the client the option to effortlessly detached and relocate if problems arise (GSA, 2011).

## 2.2.7 Design Construction phase considerations

Major design considerations include, roof structure capability and weight bearing capacity analysis.

1. The roof architecture and type of construction material guides the type of green roof needed (intensive, extensive)
2. The rooftop area accessibility, geometry, location, and size also dictates the design and construction.
3. Construction site, construction materials store, plants nursery convenience & proximity for means of transport.
4. The need for access to the green roof, staircases, construction cranes, access for taking up the construction goods to the needed level, separate maintenance access & lifts.
5. The time given for the design phase and for the construction phase, including maintenance resource is respectively affects the general output on the project.

### **2.2.8 Factors affecting green roofs cost**

There are many factors that affect green roofs cost in construction to maintenance process. To mention some, The cost for waterproofing, the cost for the substrate material, costs related with various types of vegetation's to be used, maintenance and irrigation costs, and the general hardscape elements costs are mentionable.

Below is the data from the G.S.A study that shows the average cost of green roofs related to the construction materials in the U.S.

- “Waterproofing - \$100/m<sup>2</sup>”
- “Drainage and protection layers -\$20-30/m<sup>2</sup>”
- “Growing substrate, plants, and irrigation -\$100-\$500/m<sup>2</sup>”
- “Edge restraints - \$50/lin.m”
- “Paving, decking, flooring - \$200- 400/m<sup>2</sup>”
- “Balustrading -\$150-\$300/lin.m”
- “100,000L tank, pump, and associated equipment \$25,000”

### **2.2.9 Types of green roofs that are appropriate for Addis Ababa's current context.**

Various factors affects the implementation of green roof in Addis Ababa. To mention some, the general construction cost, the availability of proper materials, the accessibility of proper vegetation's, and the availability of properly skilled constructors are mentionable. As a starting point, extensive green roofs and the modular green roof systems built with local materials will be appropriate due to their ease and economic soundness. A structural engineer who built a green roof on his building in Addis Ababa also states during the interview that, “most of the Addis Ababa's pitched and flat-roofed buildings can support the load of extensive and the green roof types without any modification”.

## 2.3 Distinctive benefits that roof gardens / green roofs offer in the existing urban fabric.

- When we create green spaces using green roof systems, there will not be a need no scarify a large amount of valuable land.(integration on already built structures)
- Green roofs provide a considerable resource for the effective utilization of existing rooftop areas. This is, to enhance stormwater management system and its costs (reduced overflows of collective sanitary and stormwater on the city level sewage systems).
- Roof gardens have a good potential for effective utilization of vacant rooftop spaces as a potential to improve the overall urban biodiversity and ecosystem services.
- They can be used as an invaluable resource for utilizing the existing rooftop spaces to reconnect the inner city community with nature again. As the same time they help to improve the air quality and reduce various problems such as, psychological problems and the lack of recreational spaces.
- The utilization of the rooftop spaces can be used as as a potential to decrease building temperatures and to minimize energy costs for air conditioning.

GR systems also provide other substantial benefits for the overall city structure such as, roof longevity, lower maintenance costs for structures, better acoustics, and improved aesthetics.

GR also has good potential for urban economic development by generating a new section of construction industry that creates a job opportunities for various types community sections.

A Report by the United States, General Services Administration describes:

*“Green roofs provide a **payback** (based on a 50-year average annual savings) of approximately **6.2 years nationally** (internal rate of return of 5.2%) and **6.6 years in Washington DC** (internal rate of return of 4.2%), and conservative analysis puts the average life expectancy of a green roof at 40 years, versus 17 for a conventional roof.”* (GSA, 2011).

## 2.4 Major Green roof benefits that are vital for densified urban areas.

### 2.4.1 Major Green Roof environmental Benefits

The key environmental benefits of roof gardens and green roofs are:

- Building temperature regulation Cooling and Building Energy Efficiency
- Carbon sequestration
- Stormwater Flood Control during the rainy season.

- Urban Dirt and dust mitigation.
- Biodiversity and habitat conservation
- Air quality control
- Reducing the Urban Heat Islands effect.

Extended building roof life span

- General buildings and structures roof longevity.

#### 2.4.2 Better stormwater management for the deified urban fabric providing permeable surfaces to infiltrate water slowly.

Flood Control during the rainy season is very challenging, especially in areas where most of the ground surface is sealed with non-permeable materials causing water to not infiltrate appropriately to the ground. The additional stormwater overflow could bring several urban complications such as, disturbs the city's stormwater management system and several city infrastructures, wear down the river banks soil, damaging urban water quality, and health issues caused by uncontrolled sewage system.

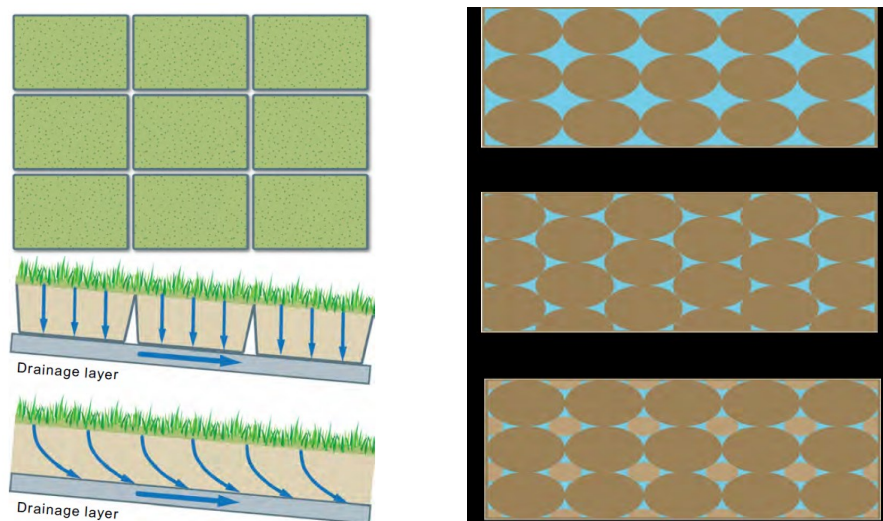


Figure 8 Diagram showing water flow and retention capacity of green roofs. Image source (GSA, 2011)

A Report by the United States, General Services Administration describes:

*“Green roofs can form a key part of a site-level stormwater management plan, reducing peak flow rates by up to 65% and increasing the amount of time it takes for water to flow from a site into the sewer by up to three hours, depending on the size of the roof and the distance the water has to travel.”* (GSA, 2011)

We can realize from the above study that, green roofs can be used as invaluable tool for city-level smart stormwater management at the same time providing several additional ecosystems/environmental services.

### 2.4.3 Being a vital tool for urban biodiversity and habitat conservation in the existing densified urban fabric.

Since urban biodiversity is a critical element in a typical urban environment, its habitat should be conserved well. Due to the loss of the conventional ground-level biodiversity habitats for various reasons, the need for alternative urban biodiversity habitat is critical especially in densified urban parts such as Addis Ababa's newly emerging central urban fabric.

Again the Report by U.S General Services Administration mentions that, Green roofs predominantly the intensive types could be designed to combine plentiful urban habitats and related microclimates that will deliver suitable conditions for a diverse plants types and urban wildlife to flourish. Roof gardens /green roofs can also be created to simulate local natural habitats, increasing the usable area available for indigenous species to flourish. This can help to restore the indigenous biodiversity eventually. (GSA, 2011).

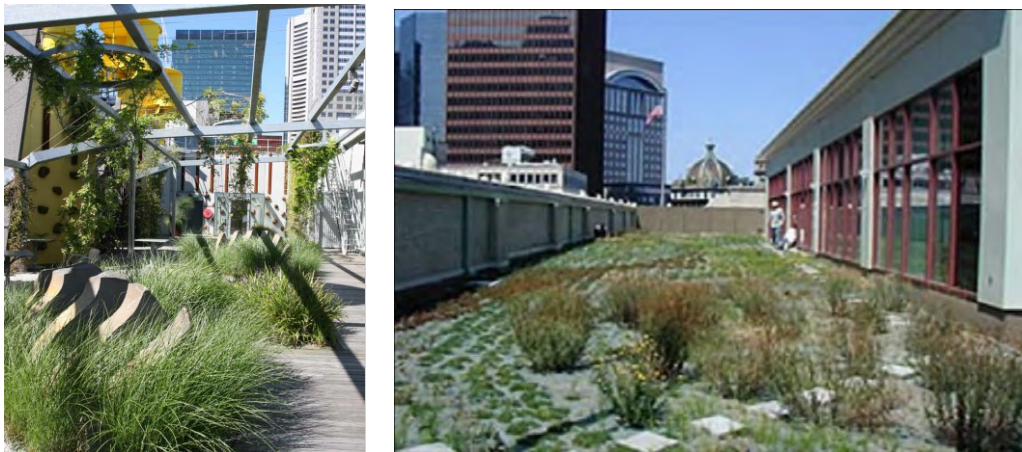


Figure 9 Various Rooftop gardens. Image sources: (Duda, 2009) & (GSA, 2011)

### 2.4.4 An invaluable tool for urban heat islands effect reduction.

Addis Ababa is now facing a huge urban heat island effect. Currently due to the absence of a proper coverage of conventional green spaces between the buildings and various structures (L & T, 2016). The result of this is an increased heat island effect that challenges the inhabitants to live to circulate in the city properly particularly in summer.

Numerous studies including the GSA study's mentions, green roofed building exterior temperatures is just about 30–40oF chiller than the conventional rooftop surface temperature in the sunny season. This studies also show that, green roof system consisting 50% the roof area in the urban fabric possibly will cause urban level chilling through the harsh sun hours and seasons. Predominantly when roof gardens joined with various urban green infrastructures such as street tree and others, the result will be significant.

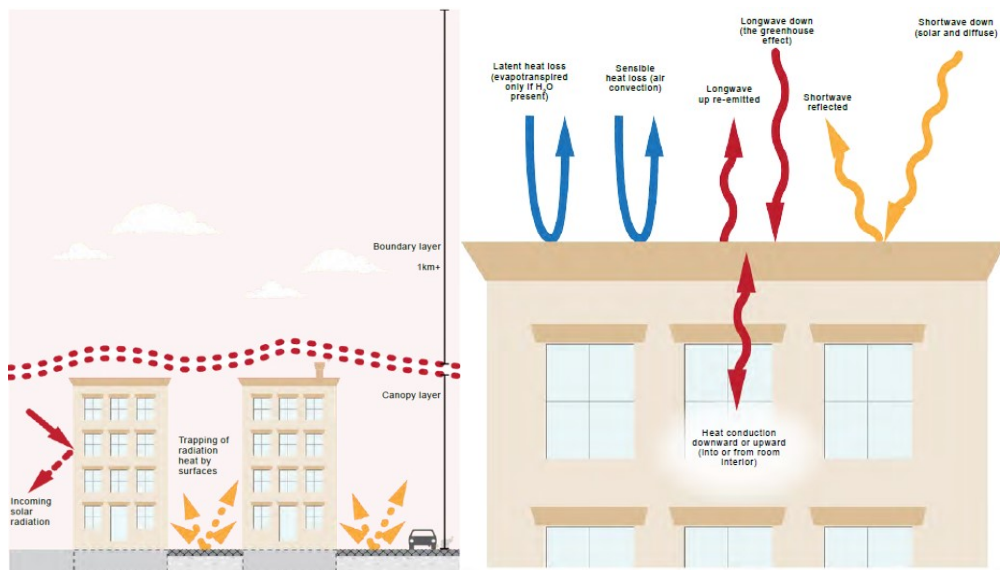


Figure 10 Surface-energy balance, Image source (GSA, 2011)

### 2.4.5 An instrumental tool for building energy consumption reduction.

Addis Ababa used to be chiller and moderate to live previously, as a result it doesn't need an artificial cooling and ventilation system for its buildings. Building designers used to easily ventilate these buildings using passive or cross ventilation system, that needs no energy for most locations. But recently, the microclimate and the macro climate changed significantly that, buildings needed an AC system for temperature regulation, costing more resources and energy. Green roofs and roof gardens could be an instrumental tool to cope up with these types of problems by creating a natural insulating layer at the same time providing other social & environmental services.

Several Studies as well as the GSA study's mentions, at summer, green roofs can also be used as an insulating cover, decreasing solar heat radiation and transfer by decreasing heat to enter from a building's surrounding to inside of the building up to 72 %. Green roofs also enable buildings to conserve energy efficiently by regulating the inside temperature during the winter season. This is by retaining the normalized air inside the building as an insulation layer to reduce heating loss.

### 2.4.6 A key resource for urban agriculture

Since Addis Ababa is gaining most of its food supply from the rural areas and from imported food items, urban agriculture is a good alternative that helps to maintain a sustainable urban food supply. Since most of Addis Ababa's land is consumed by construction, there will be a very small area left for ground-level urban agriculture. Roof gardens could be an insignificant tool to replace the lost urban agriculture lands in the inner city at the same time helping to flourish the sustainable urban farming economy. Some Studies including the GSA study's shows plants that grow in a conventional ground when compared to the green roofed, the

rooftops plants will experience lower damage from animals, pests and other harms. Rooftop gardens also increase the local economy through job creation.

### **2.4.7 A useful tool for improved air quality**

Since Addis Ababa is facing a dust and similar pollution, green patches absorbing this type of pollutants should be considered as alternative solutions.

Green patches can be used in the urban areas to eradicate air contaminants such as carbon dioxide and other toxic gases. A roof garden success at refining air urban areas quality can be determined by the type of the green roof system (extensive/intensive). One good example is the improved surface area of (vegetation's) coverage that can be used to emit air pollutants (GSA, 2011).

### **2.4.8 A better roof longevity for several years**

Roof longevity could be an additional benefit for Addis Ababa buildings. By decreasing the maintenance cost and time, the roof gardens could be used as a shield to protect the roof. Appropriately fitted roof gardens could help to double the lifetime in years avoiding replacing of roofs

### **2.4.9 General Social Benefits**

Socio-Economic Benefits:

The key socio-economic benefits of roof gardens and green roofs are:

- Recreational and garden use for the inhabitants
- Potential for improving urban food security
- Improved Aesthetics and quality of life for the residents of the city.
- Optimized outdoor indoor acoustics
- Energy conservation (minimizing artificial air conditioning cost)
- Creating a Good opportunity for urban agriculture & Job generation

Quantifiable social benefits includes, considerable extra green space that positively impacts the health and wellbeing of building occupants and surrounding inhabitants.

#### **Potentials to improve urban food security**

Rooftop greens in cities can offer about three quarters of the eatable vegetables need from the city, a study from Bologna, Italy, shows If wholly suitable roof space were roof gardened for urban agriculture, rooftop greens in the city can offer about 12 500 tons of eatable vegetables a year at the same time as also providing various ecosystem services, the scholars say any

vacant roof space in an urban buildings embodies an opportunity to supplement the city's green infrastructure. Metropolitan green places and infrastructure, which contain rooftop gardens, deliver benefits mutually for wildlife and society. They also increase urban biodiversity to form green networks, acting as a corridors for urban wildlife. Furthermore, they decrease the urban ecological footprint by cleaning the contaminated air, decreasing noise and CO<sub>2</sub> releases, and regulating microclimate (F, D, & L, 2014).

In the year 2010, Bologna turns out to be the first Italian city to experiment rooftop vegetable gardens on public buildings, a section of the project controlled by the local government, university, and a non-profit group. Investigators surveyed the experiment over three years (from 2012 and 2014). Throughout this period, rooftop growers produced lettuce, black cabbage, chicory, tomato, aubergine, chili pepper, melon and watermelon, one or the other way of, in plastic pipes, salvaged pallets packed with compost or on polystyrene boards fixed in tanks, similarly made from second hand pallets (F, D, & L, 2014).

#### **2.4.10 Potentials to improve aesthetics and quality of life**

Aesthetics is a major issue for most Addis Ababa's buildings, since the lack of green spaces and green coverage contribute for reduced esthetical value, Green roofs can offer a beautiful space for residents, and for the overall scenario of the neighboring buildings. Intensive roofs gardens can be a place of retreat and recreation for individuals who are living and working in the building. They also help to reduce anxiety at the same time increasing residents work efficiency (GSA, 2011).

#### **2.4.11 A useful tool for urban job generation and economic development**

Roof gardens offer possible job creations for various types of community class. They can offer investors and developers sought-after building value when compared to the non-green roofed structure. Since Addis Ababa is facing several issues related to unemployment of youths, a green roof construction and maintenance industry could be a good economic development opportunity.

#### **2.4.12 Relevant benefits for Addis Ababa's case**

Since it is ideal to prioritize and classify the essential and necessary benefits that are very urgent particularly to the current context of Addis Ababa, the following major benefits are outlined as a priority-

Better stormwater management

Urban heat islands effect reduction.

Improved air quality

Improving aesthetics and quality of life

Various socio-economic benefits including urban agriculture, job generation, and providing recreational space for improving the inhabitant's mental health.

## **2.5 Major constraints and limitations that are a barrier to the widespread implementation of green roofs.**

### **2.5.1 Introduction**

Since there are several obstacles which are hindering the green roof/roof gardens in the urban fabric, the following issues are selected as a major and critical factors in the developing world.

1. Disbelief and doubts in the introduction of new technology particularly in the construction industry
2. Guaranteeing the building structure supporting capability for the additional load.
3. Higher Cost concerns related to the construction and maintenance
4. Maintenance and preservation (leakage issues and other similar concerns), issues including accessibility issues in the construction phase.
5. Lack of detail and proper guidelines that are specific for the design regulation and construction phase. Absence of proper incentives for developers that are wanting to incorporate green exteriors in their buildings.

### **2.5.2 Doubt and disbelief in the introduction of new technology**

Addis Ababa's construction industry is in its early stage. However, it grew rapidly in a huge scale without the introduction of new construction systems, methods and materials. This can be clearly observed when comparing with many developed countries. The same applies to the introduction of green exterior systems in the existing construction industry, Dudas research also demonstrated that there is a general risk in various sectors which mainly concerned in constructing green exteriors. This means there a fear that, there will be a chance some element and system in the new green exterior might go wrong than usual nongreen exteriors. We must have a local built examples to demonstrate to the developers that, green roofs are unproblematic if they are constructed well and they recompense in the long run.

### **2.5.3 Fear of issues associated with the green roof leakage and other similar maintenance problems**

The other issue identified by Jason's research is, what will occur when structures/buildings are left alone without maintenance and they will not capable to be well functional. Contrasting with the usual buildings where spaces can be stayed up if vacant or uninhibited, green roofs and green exteriors may perhaps create threats for neighboring property-owners or the nearby urban community. These issues include uncontrolled rodent breeding, the spread of unwanted

plants increased fire and related threats, and possibly unwanted odors from decomposing plants and other organic substances (Duda, 2009).

#### **2.5.4 Cost related limitations**

As Jason's paper mentions, numerous owners choose cheap and minor risk building exteriors. However, construction prices for green roofs can be diminished by localized material construction and application experiences. But there will be a considerable construction and design cost since the nature of the maintenance and application need a professional's contribution (Duda, 2009).

#### **Green roofs design construction and maintenance cost**

The general cost can be summarized by Design cost + Construction Materials cost + transportation of materials cost + Construction labor cost. Other costs include Maintenance and conserving costs. Apart from the other conventional costs, opportunity cost is the significant cost that developers usually forget when considering alternative building exteriors. The opportunity cost can be described as, the cost of consuming the rooftop space for supplementary programs such as electric generating solar panels and other types of storage and machines.

Another design cost is the analysis for engineering related assessments such as the structural capability of the roof to support the green roof, sanitary design, aerodynamics, and similar disciplines. Aesthetics related design costs include, roof architectural design cost, and Urban Planning and Urban Design costs.

Major softscape and hardscape costs include, landscape Architecture costs (rooftop space overall softscape and hardscape design cost), and botanist cost for vegetation's types specifications. Last but not least, other costs include cost for the management of organic waste, storage, and removal are mentionable.

#### **2.5.5 Absence of appropriate Policy, Standards, and implementations**

One of the significant barrier hindering the widespread application green roofs is the absence of proper regulation and policy. This barriers create a system that is not willing to give incentives for such type of alternative green solutions. Jason's research mentions, government body's frequently do not take action until to some degree that terrible or disastrous thing take place. He also describes the predominant concerns are; there are almost no strategies or guiding principle that are set by the government in this specific area.


Some of the issues that hinder the government from taking action are, it is indistinguishable whether land use approach or building type approaches are appropriate to follow as a mainstream urban green development framework. Microclimate and other environmental elements need to be well thought-out in the city level preparation of green roof/roof garden plan or other types of alternative green infrastructure guidelines.

## 2.6 International practices

### 2.6.1 Mint Hotel

#### 2.6.1.1 Context

“The Mint Hotel is situated in the East of the City of London close to Tower Hill and Fenchurch Street. There are two green roof areas on Levels 2 and 11, additionally, the Mint Hotel contains the tallest living wall in Europe and the hotel has been designed with environmental quality in mind, of which the roof and living wall play an important part” (London Corporation, 2011).

Mint Hotel, Pepys Street		
Description	Technical description	
<p><i>Client name: Mint Hotel</i></p> <p><i>Green roof supplier: frosts landscape construction ltd</i></p> <p><i>Architect: Bennetts associates architects</i></p> <p><i>Landscape architect: none</i></p> <p><i>development type: Hotel</i></p> <p><i>date completed: December 2010</i></p>	<p><b>Total Roof Area (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• 1195</li> </ul> <p><b>Roof Area Greened (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• Sedum – 385</li> <li>• Hard Landscaping with planters - 505</li> <li>• 75% green roof coverage</li> </ul> <p><b>Build Cost (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• Level 2 - £100</li> <li>• Level 11 - £150</li> </ul> <p><b>Type of Green Roof</b></p> <ul style="list-style-type: none"> <li>• Extensive Sedum blanket on Level 2</li> <li>o Substrate Depth: 130mm</li> <li>• Semi-Intensive green roof at Level 11 with inaccessible sedum and wildflower area and accessible paved terrace with planters.</li> <li>o Substrate Depth: 130mm</li> </ul>	 <p><i>Figure 11 Mint Hotel (London Corporation, 2011)</i></p>
<p><b>Barriers Faced:</b></p> <ul style="list-style-type: none"> <li>• Maintenance could have been a potential barrier for such a design, but the clients were supportive of the design from the initial stages.</li> </ul>	<p><b>Biodiversity Consideration:</b></p> <ul style="list-style-type: none"> <li>• Level 11 contains Bee Hotels, providing habitats for bees.</li> <li>• Deep substrate layers and plants were chosen to attract a vast array of wildlife species, but importantly also to be sustainable and create microhabitats.</li> </ul>	<p><b>Further Information:</b></p> <ul style="list-style-type: none"> <li>• Sustainable construction and involvement with contractors from the initial stages.</li> <li>• Fully understand the maintenance requirements for the designed green roof as this could potentially affect its letting potential.</li> </ul>

*Figure 12 Mint Hotel general green roof context Source: (London Corporation, 2011)*

## 2.6.2 Pocket Habitat, Exchange House, Broadgate Estate

### 2.6.2.1 Context

“Pocket Habitat was developed by Arup for British Land to increase the biodiversity of their existing buildings and urban land stock after all other green roof systems were viewed inappropriate due to the environmental limitations related with retrofitted green roofs” (London Corporation, 2011).


Pocket Habitat, Exchange House,		
Description		
<p><i>Client name: British land</i></p> <p><i>Green roof supplier: Arup &amp; Sky gardens, grey 2 green</i></p> <p><i>Development type: office</i></p> <p><i>Date completed: May 2011</i></p>	<p><i>Roof Area Greened (m<sup>2</sup>):</i></p> <ul style="list-style-type: none"> <li>• 180</li> <li>o 504 Pockets</li> </ul> <p><i>Build Cost of Green Roof:</i></p> <ul style="list-style-type: none"> <li>• £9100</li> <li>o £50m<sup>2</sup></li> <li>o £18 per pocket</li> </ul>	 <p><i>Figure 13 Pocket Habitat, Exchange House, (London Corporation, 2011)</i></p>
<ul style="list-style-type: none"> <li>• <i>Pocket Habitat is easy to retrofit to existing roofs due to the compact and lightweight design. Installation and removal can be done manually with little specialist equipment. The flexibility of the pockets also offers an immediate temporary greening on development sites.</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>When the modular pockets are joined together they make a carpet of vegetation that can be designed for visual or biodiversity features. 2.8 pockets can be installed per m<sup>2</sup> and can be installed on awkwardly shaped roof spaces as no cutting is required.</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>The modular planting pockets can be individually personalized to promote biodiversity with varying combinations of depths, locally sourced substrate materials and seeded with native plant species. Each individual pocket emulates the natural environment by providing shade, shelter, and exposure to sunlight. Pocket Habitat, therefore, be a valuable tool in successfully reaching and exceeding the needs of Biodiversity Action Plans (BAPs).</i></li> </ul>

Figure 14 Table showing the general context of the Pocket Habitat, Exchange House, Broadgate Estate green roof. Source: (London Corporation, 2011)

## 2.6.3 Unilever House

### 2.6.3.1 Context

“The roof at Unilever House was rebuilt during the refurbishment of the building creating intensive roof terraces on Levels 8 & 9 that are heavily used by the tenants. Unilever House was constructed in 1929 prior to the implementation of the St Paul’s Height restrictions with some parts of the roof exceeding this” (London Corporation, 2011).

Unilever House		
<p><b>Description</b></p> <p><b>Total Roof Area (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• 2614</li> </ul> <p><b>Roof Area Greened (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• Hard and Soft Landscaping – 1825</li> <li>• 70% of green roof coverage</li> </ul> <p><b>Build Cost of Green Roof:</b></p> <ul style="list-style-type: none"> <li>• £514,650</li> </ul> <p><b>Type of Green Roof:</b></p> <ul style="list-style-type: none"> <li>• Intensive Terrace Levels 8 &amp; 9</li> </ul> <p><b>Planter Substrate Depth:</b> 200mm</p>	<p><b>Roof Area Greened (m<sup>2</sup>):</b></p> <ul style="list-style-type: none"> <li>• 180</li> <li>o 504 Pockets</li> </ul> <p><b>Build Cost of Green Roof:</b></p> <ul style="list-style-type: none"> <li>• £9100</li> <li>o £50m<sup>2</sup></li> <li>o £18 per pocket</li> </ul>	
<p><b>Barriers Faced:</b></p> <ul style="list-style-type: none"> <li>• The existing roof was not as structurally sound as originally thought. A portion of the roof had to be rebuilt to support the roof garden.</li> <li>• Services were built around the roof garden plans encouraging minimal plant on the roof and innovative design techniques.</li> <li>• A small structure on the roof required planning permission despite parts of the original roof being higher than current height restrictions.</li> </ul>	<p><b>Further Information:</b></p> <ul style="list-style-type: none"> <li>• Much of the plant equipment was moved to the basement to allow the maximum available space for the roof garden and to maintain a tidy roofscape. Where plant was on the roof innovative design methods were used such as stacking cooling towers to conserve space.</li> </ul>	<p><b>Biodiversity Consideration:</b></p> <ul style="list-style-type: none"> <li>• Biodiverse plant species have been planted within the cradle cleaning zones as these zones are less likely to be disturbed than in the general roof garden.</li> <li>• No specific species have been targeted for this roof garden. However, it is hoped that with the variations in materials, substrate depths and plant species the roof garden does support biodiversity.</li> </ul>

Figure 15 Unilever House general green roof context. Source: (London Corporation, 2011)

## 2.6.4 M-Tray modular green roof system

### 2.6.4.1 Context

All the elements required for a successful green roof have been measured and installed into the **M-Tray** modules at the nursery, so users can feel confident that the plants, growing medium and filtration components are suitable and compatible, and at the correct level to give strong, healthy growth over the long term. The trays are grown for a period of at least 6 months and all will have been through at least one spring growing season; so the plants are well established, healthy and strong, and fully integrated into the substrate (unlike sedum blankets, which are not) (Wallbarn Ltd, 2019).

M-Tray modular green roof system		
<p><b>Description</b></p> <p>The module measures 500 x 500 x 100mm. As four units make up exactly one square meter estimating is a far easier process. There are fewer drainage holes than in previous versions to keep water within the green roof system for longer. This allows the plants to absorb more rainfall,</p>	<p><b>Speed</b></p> <p>It can be installed at least twice as quickly as roll-out systems. A team of contractors can easily install approx. 400 square meters in a day. It is also an instant green roof.</p>	
<p><b>STEP BY STEP INSTALLATION</b></p> <p>M-Trays have all the necessary elements contained within them. So no bulk bags filled with sharp aggregate or sheet membranes blowing away in the wind. M-Tray modules are transported to site on strapped pallets for an easy, clean delivery. They can then be craned safely onto the roof if necessary.</p>	<p><b>Accessibility</b></p> <p>M-Tray can be hand balled into even the most awkward areas, even carried through a window (pictured) if necessary. They are the perfect retro-fit product.</p>	<p><b>KEY ADVANTAGES</b></p> <p>The advances made in the design of the M-Tray® model include:</p> <ul style="list-style-type: none"> <li>• deeper cavities for extra root growth</li> <li>• optimum drainage leading to stronger plant growth</li> <li>• more established vegetation at point of installation</li> <li>• more efficient transport and packaging</li> <li>• exactly 4 units per m<sup>2</sup></li> <li>• easier to carry trays with smooth handles</li> <li>• a closer connection between trays for more seamless plant growth</li> <li>• no sharp edges, less risk to the membrane</li> <li>• nothing spills out, less mess</li> <li>• made from recycled plastic with recycled substrate</li> <li>• less packaging, less waste</li> </ul>

Figure 16 M-Tray modular green roof system details Source: (Wallbarn Ltd, 2019)

## 2.7 Contextual review

### 2.7.1 The ETHIOPIAN NATIONAL URBAN GREEN INFRASTRUCTURE STANDARD review (Local guide-line review)

The Ethiopian national urban green infrastructure guideline is a guideline mainly sets the minimum strategies and information for further green infrastructure development in Ethiopia to future development. As the introduction describes-

*“The Ethiopia National Urban Green Infrastructure standard aims at setting the basic minimum standard requirements for Urban Green Infrastructure (UGI) development and management. This UGI standard development has done based on international and national cities experiences in UGI development and management.”* (MUDHo, 2015).

Since this guideline only describes and show the general idea of various types of urban green infrastructures and how to implement them, it does not show in detail guidelines including particular specifications, design standards, and other essential details to aid the developer. The green roof/roof garden section describes various preconditions and suggestions, but again it doesn't show the detail of the specific design requirements or alternatives for various types of roof architectures in Addis.

Some of the sections the guideline try's to discuss the Introduction about the green roof in general. This guideline tries to define green roofs as follows, *“A ‘green roof’ is a roof or deck onto which vegetation is intentionally grown or habitats for wildlife are established. Each green roof is unique and provides a different type of habitat, water storage capacity, and energy-saving potential.”* (MUDHo, 2015).

The guideline proceeds with several general strategies such as, respective experienced bodies should encourage the creation of green roofs to provide a better-quality urban climate in the city fabric. The guideline also tries to discuss that various professionals such as contractors, urban designers, and landscape architects, have to be properly educated with the paybacks of roof gardens for the highly densified inner city.

Some general technical suggestions include general suggestions such as, the plant life layer requires at least 8 cm substrate and waterway should be well considered. It also discusses that landscape architects and contractors who plan, supervise and construct the green roof must aim to build lifetime contracts including to maintain and preserve the green roof well and decrease the cost. During the maintenance period, the guideline suggests that streets, gutters, and waterways must be unpolluted and unclogged with overgrown plants and organic wastes from the green roof avoid obstruction. Other suggestions include, Experienced government establishments must control that developing industrial buildings having larger > than 250m<sup>2</sup> roof space and a rooftop angle reaching up to 10° slope must have a green roof or must have appropriate rainstorm water controlling system on the ground level.

## 2.8 Summary

### 2.8.1 Concerns encompassing enforcement, planning, and design to construction

At present, there are no specific and detail city level planning guidelines and construction regulations guidelines for green roofs/roof gardens in Ethiopia. Further design guidelines and regulations should consider various issues such as, numerous types of roof architectures, building set back, overshadowing of neighboring buildings appropriateness, microenvironment consideration, aesthetics study with building architecture, planning permits. As a result developers can have a clear guideline for proper green roof application in the context of Addis Ababa.

#### Attentions in Architecture, Landscape architecture, and Engineering level

First of all, before designing and starting construction of any green roof, we must consider the overall roof weight bearing capacity, by a support of a professional structural engineer. If the buildings are on the design stage, we should also consult the structural engineer about the green roof and its relative general additional dead load.

Other issues such as, waterproofing, stormwater, and irrigation drainage lines should be well thought before starting the construction by a professional sanitary engineer. Because of the dry nature of vegetation's they are prone to fire, so there must be a well-thought fire safety system and alternative emergency rout systems to avoid such scenarios. Other considerations include, general maintenance and energy sustainability considerations during the lifetime of the green roof system.

#### Concerns in construction level (in particular related to contractors)

A critical issue that one must consider when contracting green roof system is, the availability of alternative access means to the rooftop by various means such as, cranes, ladders, lifts, and stairs without disrupting the regular activity in the building. This is both for maintenance and construction phase.

The availability of proper waterproofing membrane must be considered well, since most concerns are raised with leaking roofs. Specialist contractors focusing on such types of alternative green solutions should be well supported by various incentives, particularly by the city administration to help and to widespread this alternative urban green infrastructures. In the maintenance period, the management of organic waste from the green roofs should be well thought and considered to avoid unnecessary problems in the urban environment. Some lifetime maintenance concerns include the, clogging of stormwater lines in urban level due to un-properly managed organic waste from the roof gardens, and some plants might overgrow and disrupt the public way and other public space if not properly pruned.

## 2.8.2 Encompassing design guidelines and modular green roof systems

Successful international practices such as the m-tray modular green roof systems demonstrate that, green roofs can be designed and installed in a very convenient mechanism if there is a little creativity or effort. A study on the m-tray modular green roof system reveals that the m-tray system could be a great system that uses easy techniques that are easy and adoptable for the context of Addis Ababa. Since this system is constructed with materials that could be available in Addis Ababa, it will be a good alternative for further customization studies. The basic elements of this green roof, which are the plastic trays can also be manufactured in Ethiopia by local plastic factories.



Figure 17M tray Modular green roof system source: (Wallbarn Ltd, 2019)

# Chapter 3 Method

## 3.1 Introduction

This research paper attempts to reveal the realities of green roofs and their outcomes in Addis Ababa by using existing data and information from various primary and secondary sources. Most of the secondary data are collected from various sources of unpublished & published documents that are gathered from relevant governmental and non-governmental organizations, individuals and as well as from several local and international sources research papers.

### 3.1.1 Types of research

This research comprises of mutually descriptive and explanatory research techniques. The Descriptive exploration attempts to see and investigate a given problem or condition which is mentioned in the first chapter. This technique tries to breakdown the factors to deliver feasible evidence and facts about the current condition of the respective issue. Whereas explanatory approach of study is used to clarify the basic questions mainly the how and why questions related to the presence of the condition, association, connection and correlation among two or more features of the given issue.

Various methodologies are used to address each specific questions. As part of the methodology, qualitative research approaches are used for this research since the condition of the question makes it difficult to make it quantitative research. The reason for this is there are few numbers of attempted and constructed green roofs in Addis Ababa which makes it difficult to mass sample and quantify these samples as a model of the overall and general situation of the problems. For these reasons, the unstructured approach is used in this research for better flexibility as a tactic for studying all features of the research process.

The central objective is to study the differences in a phenomenon, condition or circumstances of current which mainly contain the explanation and description of the observed situation, an explanation, and interpretation of different opinions of diverse professionals and people concerning the issue.

## 3.2 Methodology 1 (For specific research question 1)

Data and materials used in this section are from mixed resources that are gathered from primary and secondary data.

### (1) Library research

- (i) Analysis various recording of notes, publications and content analysis on green roof systems.

(ii) Analysis of local documents

(2). Contextual study (Case study assessment)

Conducting investigation on selected case study's as a tool for obtaining the needed information to address the research questions.

(i) Non-participant direct observation

(ii) Recording of the existing situation using various Medias

(3) An in-depth interview with respective stakeholders.

### 3.2.1 Primary data

Data that are captured from primary sources consist of the problem, the potential, and as well as the real-life causes for unsuccessful widespread adaptation of green roofs systems in Addis Ababa, which mainly focuses on rare initiations and pilot developments of existing green roof projects undertaken by few individual developers to some extent.

### 3.2.2 Secondary data

Secondary data predominantly contain locally and internationally written literature focusing on alternative green infrastructures mainly on urban level green roof/roof garden systems, cases and applications for the sustainable and climate resilient city. Further additional data also includes previous local guideline review on green infrastructure and sustainable city.

## 3.3 Methodology 2 (For specific research question 2)

Data and materials used for this section are mainly gathered from secondary resources. At the same time, very few primary data resources are integrated.

(1). Study on international sources for innovative GR products.

(i) Study of various publications and related contents

(ii) Study of Modular GR designs

Conducting investigation on successful international modular GR system as a case studies to obtaining the road map for customization.

(2) Local available materials investigation for the use of modular green roofs.

To understand the context using local market assessment as well as using an in-depth interview.

## 3.4 Data sources and collection techniques

Primary data sources for this research are purposively identified cases in the city and professionals in the field whereas secondary data sources are literature, policy documents, and reports. Due to an absence of well-established green roof industry in Addis Ababa and its newness to the construction industry, most of the data is collected from the World Wide Web publications and case studies that have a successful experience in introducing this system.

### 3.4.1 Primary data source and collection techniques

Personal observation and experiences; building occupiers, owners, and managers, the residents in the study area, concerned government officials and professionals were the main sources of the primary data. The following methods were used for data collection.

#### 3.4.1.1 Field observation method

Field observations & surveys of existing green roofs in Addis Ababa is made focusing on issues of functionality, shortcomings of the construction process, maintenance, ecological and social benefits, sustainability & appropriateness.

#### 3.4.1.2 In-depth Interview

In-depth interview was conducted with professionals in the field focusing directly on the subject matter used to identify key challenges, potentials, and opportunities in the process of construction, design, and management of green roof systems in Addis Ababa.

Major participants of the in-depth interview include Landscape Architects, Architects, Structural Engineers (consultants) and owners, Contractors, and Designers. The interview was conducted both informal and on informal manners to fit the situation. Apparently, this helped, to clearly access & distinguish the overall conditions of green roofs in Addis Ababa. Moreover, the interviewee's experience helped to capture former experiences of constructing green roofs in terms of their successful application & failure. In addition to these, relevant information was captured via using tape recorders, photographic media, use of audio-visual recording devices and other similar devices where possible.

#### 3.4.1.3 Case study

A case study was conducted through selecting cases within Addis Ababa using predefined criteria. The criteria are stated as follows:

#### **Case study selection criteria.**

This research paper selected two case studies for further investigation purposes. The selection criteria are based on -

- Building/residence with green roof
- The convenience for access, openness, and willingness for research and data collection.
- The capability to portray and showcase the main issues facing the majority of green roofs and the generic buildings in Addis Ababa.
- The availability of adequate data's & information from developers and consultants.

Accordingly, two cases are selected out of very few and a small number of rare green roofs found in Addis that can showcase the scenario from public building and from residential building aspects.

### - **Case study one**

Project: Hope University College, Addis Ababa, Ethiopia.

Client: Hope Enterprise, Addis Ababa & "Word en Daad", Gorinchem, the Netherlands.

Description: New educational complex. Floor area 12.000m<sup>2</sup>. Completed in 2012.

Associated architect: Abba Architects, Addis Ababa, Ethiopia.

### - **Case study two**

Project .residential building in Ayat with an existing and active green roof that is cultivated by the residents currently.

- Location Ayat residential area.

-Project client and contractor Ato Tewodros woldeamlak. (Civil engineer)

## **3.4.2 Secondary data sources and collection techniques**

The majority areas that are used to gather the secondary data are hard copies and soft copies which mainly consists: published books and journals; unpublished norms and standards, reports, brochures journals, reports and maps from the internet, libraries and office stacks. Accordingly, the data capturing method was through reading and note-taking; scanning hard copies as well as; browsing and extracting through trusted websites.

## **3.5 Data analysis and interpretation techniques**

Computer Software's including Microsoft Office Word, Microsoft Office PowerPoint, and other similar software were used to create, graphics, write texts and to clearly show the evidence and the situation on this research.

Audio recorder is used throughout the interviews, at the same time the photographic camera is used to capture the status of the selected sites. Auto CAD files are also used to analyze the first design and intentions of the consultant/owners. The gathered secondary and primary data also were studied, and the information is triangulated in reference to each other.

### **3.6 Presentation techniques**

Several graphics such as plans, sections, elevations and site photographs of the green-roofed buildings which are the case study's in this research were used to make the object clear to the reader.

This research comprises helpful solutions for potential difficulties and problems on the green roof system in the current situation of Addis Ababa, which is discovered over the research process. The solutions are to selectively, approach on specific aspects of the overall challenges and to focus and to come up with adapted design modifications for some of the difficulties in the context of Addis Ababa. This is shown by designing prototype samples, recommendations, and design guidelines that are supported with detail drawings and other graphics.

# Chapter 4 Results & Discussions

## 4.1 RESULT - 1

### 4.1.1 Introduction

Existing Green roofs in Addis are very scarce, and almost all of them are found in a decentralized manner throughout the city. To mention some of the existing green roofs in Addis, The Gulele botanical garden center building (intensive green roof) & the hope university library building with its green roof are mentionable.

### 4.1.2 Current conditions & potentials for the application of green roofs in Addis Ababa.

There is a huge potential for the development of green roofs in Addis Ababa, this is mainly because of the current construction boom resulting in the erection of many new commercial and governmental buildings having new rooftop spaces. The growing coverage of the developing rooftop spaces can be a good potential to habituate this roofs with green roof system in the city.

Since there are a limited number of successfully constructed green roofs in Addis Ababa, it is not easy to address all the drawbacks, constraints and achievements of this green roofs to implicate the overall situation only by analyzing few samples. Nevertheless, this study will try to explore as much as possible issues on the existing green roofs and their design & construction issues, to come up with better application recommendations for the city.

As mentioned earlier, green roofs offer several economic, environmental, and societal benefits for the inhabitants. These benefits range from, a better stormwater management to local amenity management, and several holistic benefits for the building occupants as well as for the surrounding community.

To mention some of the existing green roofs in Addis Ababa:

1. Hope University College (Library building) Addis Ababa, Ethiopia.
2. Gulele botanical garden meeting hall building, Addis Ababa
3. Safarian Volkswagen showroom building in Addis Ababa (around Mexico square)
4. Hyatt Regency Hotel Project, ASB Hotel Properties PLC, green roof and balcony greens (under construction)
5. There are also very rare residential buildings consisting of intensive green roofs that are found throughout the city (found here and there and they are also highly dispersed.)
6. Indian embassy project having green-roofed buildings (under construction, ABBA Architects).

### 4.1.3 Case study selection.

Two case studies are selected for investigation based on predefined criteria stated under section 3.4.1.3. These case are believed to show the scenario from public building to residential building:

#### Case study one

- Project: Hope University College, Addis Ababa, Ethiopia.
- Client: Hope Enterprise, Addis Ababa & "Woord en Daad", Gorinchem, the Netherlands.
- Description: New educational complex. Floor area 12.000m<sup>2</sup>. Completed in 2012.
- Associated architect: Abba Architects, Addis Ababa, Ethiopia.

#### Case study two

- Project .residential building in Ayat with an existing and active green roof that is cultivated by the residents currently.
- Location Ayat residential area.
- Project client and contractor Ato Tewodros Woldeamlak.(Civil Engineer)

#### 4.1.4- Result - 1 (Hope University College library building)

##### **Project: Hope University College, Addis Ababa, Ethiopia.**

**Client:** Hope Enterprise, Addis Abeba & "Woord en Daad", Gorinchem, the Netherlands. (treurniet-architectuur, 2018)

**Description:** New educational complex. Floor area 12.000m<sup>2</sup>. Completed in 2012.

**Associated architect:** Abba Architects, Addis Ababa, Ethiopia.

Data collected through - In-depth interview, site observation, and analysis of related documents such design drawings gathered from the consultant and as well as written information from treurniet-architectuur.



*Figure 18 Hope university library bird's eye view, Image source: (treurniet-architectuur, 2018).*

*“The Philosophy of Hope Enterprises highly emphasizes the change in the mentality of the youth. Not only in education but in the overall development of young people. “By using traditional shapes and compositions, the use of local materials, ecological building methods, natural and passive energy use, light and natural ventilation a strong Ethiopian awareness is carried out. Both history, present and their future. “* Source: [www.treurniet-architectuur.nl](http://www.treurniet-architectuur.nl)



*Figure 19 the green-roofed library building with the other university buildings Image source: (treurniet-architectuur, 2018).*



*Figure 20 Current status of the green roof image source: site visit*

#### 4.1.4.1 Introduction

Hope University is found around the jemo district area in Addis Ababa. The university compound consists of various types of facility buildings, including the successful green roofed library building that consists of an aesthetically pleasing green roofed surface merging with the landscape. This interesting green roofed library faced several encounters in terms of preserving the originally built green roof. According to the data gathered through observations the challenges are analyzed in different phases, which are composed of addressing the respective disciplines, the construction phase & the maintenance period.



*Figure 21 Current status of the green roof (right side, the reconstructed one, image source site visit*



*Figure 22the merging landscape with the surrounding Current status of the green roof (right side, the reconstructed one, image source: site visit*

#### 4.1.4.2 Design phase challenges

During the design phase, proper material selection, proper construction details, and clever design techniques needed to be addressed by the green roof designer. Since this green roof is almost monotonous landscape covered with lawn (grass), in plant selection, there are no significant challenges facing in the design team. Whereas there is a special focus that had to be given, since making the necessary green roof connection details properly is very crucial for the overall system. Since by its nature, it is a new type of design and construction when considered for the context Addis Ababa, details works are handled carefully.



Figure 23 the overall library architectural design panel. Image source: site visit.

As mentioned in section 2.4.7, the time given for the design phase and for the construction phase including the maintenance period respectively affected the general output of this project. Construction site and construction materials store, plants nursery proximity and availability (since there are no specialized nurseries in Addis Ababa growing specific plant species appropriate for green roofs) also dictate designers of the building.



Figure 24 surrounding of the library building. image: (treurniet-architectuur, 2018)



*Figure 25 Special connections and joints on the green roof that needed specific green roof details to avoid problems such as leakage and related issues. Image: site visit.*

Furthermore, the roof architecture and the type of construction material guides the type of green roof needed (intensive, extensive). The need for the green roof for accessing staircases, construction cranes, access for taking up the construction goods to the needed level, separate maintenance access lifts is mandatory. On this specific building, because of its gentle slope, the building doesn't needed other additional access, staircases, and cranes plans in the design proposal for the construction and maintenance purpose.



*Figure 26 The Library seen from ant's eye view, connections and joints that need a specific design detail. Image source: site visit*



*Figure 27 the Library seen from side walls, connections, and joints that need a specific design detail. Image source: site visit.*

The time given for the design phase and for the construction phase including the maintenance period is respectively affecting the general output on the project, including the sustainability of the project. This project can be a good example of how architects and consultants should consider the design stage cautiously to achieve a sustainable green roof.



*Figure 28 the Library seen from side walls, connections, and joints that need a specific design detail. Image source: site visit*

#### 4.1.4.3 Construction phase challenges

As mentioned in section 2.5.4, general cost can be summarized by Design cost + Construction Materials cost + transportation of materials cost + Construction labor cost and other similar costs including the maintenance and conserving costs. Since green roofs are new to Addis Abba construction industry, usually the contractors try to work with alternative but not appropriate materials to minimize the cost. This eventually leads to the failure of the green roof in the long run. Even unsupervised and unskilled maintenance & pruning workers damage the waterproofing membrane on the digging process. This is the same with this case study, this interesting green roofed library faced several encounters in terms of preserving the originally built green roof. In this specific project, most of the challenges faced are originated from the construction of the first green roof system and the deficiency of maintaining it properly. As mentioned before, the first constructed green roof become problematic after around 8 years of service, due to leakage and other similar issues. For these reasons, the green roof needed overall reconstruction and replacement by another contractor.

#### 4.1.4.4 Reconstructing the green roof

Serving for about eight years, due to the seepage and leakage issues on waterproofing, the complete green roof system needed to be rebuilt from scratch. The first green roof which is undertaken by the Chinese construction firm, has several dissimilar layers of elements in the green roof system in contrary to a newly built green roof. The first green roof layers consist:

1. RC SLAB
2. Bitumen painted to the slab
3. 25 cm of selected material fill
4. Geotextile layer
5. Soil
6. Vegetation (grass)

The existing (newly constructed) green roof whereas have, different layers and materials arrangement with double protection waterproofing. The layers consist:

1. RC slab.
2. Two layers of well-applied waterproofing membrane (thick waterproofing membrane comes as a roll and applied by oxygen flame by overlapping on the joints carefully.)
3. 5cm cement concrete screed to protect the waterproofing
4. a layer of plastic sheet
5. soil layer
6. vegetation (Grass)

As we can clearly see from the newly constructed green roof system, it consists a dual and more protective waterproofing system as the same time having a more protective concrete shield to protect the waterproofing from various damages in the construction or maintenance processes. As mentioned in section 2.2.4, this is because most of the Intensive green roofs

consist a denser/heavier and thick soil cover and can be vegetated and landscaped with various plant types that replicate the conventional ground-level urban parks and botanical gardens. Such types of plants need watering/irrigation throughout the harsh hot and dry seasons (Particularly in summer). Because of the nature of the composition of their dense and thick substrate layer, most types of intensive green roofs need stronger roof structure and membrane compared to extensive green roofs. As a result, this project needed a good double protection impact resisting waterproofing layer fitted to the green roof base.

#### **4.1.4.5 Maintenance phase challenges.**

One of a significant problem occurred in the hope university library green roof system is a maintenance problem. This is caused by, the absence of proper protective layer material that guards the waterproofing. In addition the unaware laborers tear the waterproofing layer unintentionally when they are digging the green roof for maintenance of the landscape. This patches eventually led to weaker joints, this at the end of the day created a loophole for water to leak to inside, and cause various serious problems in the building.

#### **4.1.4.6 Current condition**

The hope university library green roof is currently in excellent condition, and it is functioning very well in the meantime being aesthetically pleasant. The key for its exceptionally good condition are, the workmanship quality and the selection of proper materials. This made it sound & effective that, even on the interior there are no visible leakage spots. The following pictures show the current condition.



*Figure 29 as we can see from these image, the reconstructed interior of the library has no leakage issues and being in very good and exceptional condition up to now. (Reading space).  
Image source: site visit*



*Figure 30* this images show the reconstructed interior of the library is have no leakage issues and being in very good and exceptional condition up to now. (Reading space). Image source: site visit



*Figure 31* Roof slabs being in clear and clean manner (same as conventional roofs without green roof). Image source: site visit



*Figure 32* (View from the open down) again reading area and Hallway Roof slabs: similarly being in clear condition same as conventional roofs .image source: site visit



*Figure 33 Hall way Roof slabs: similarly being in clear and clean manner same as conventional roofs without green roofs. Image source: site visit*



*Figure 34 again reading area and Hallway: Roof slabs similarly being in clear condition same as conventional roofs .image source: site visit.*



*Figure 35 Front entrance to the library (in exceptionally good condition). Observe the sloping connections. Image source: site visit*



*Figure 36 (View from the roundabout) Front entrance to the library (on exceptionally good condition) observe the sloping connections image source: site visit*

## 4.1.5 Result-1 (Residential building in Ayat, Addis Ababa with extensive) green roof

### 4.1.5.1 Introduction

This building is found in Addis Ababa in the district locally known as the Ayat neighborhoods. Both the developer and the contractor is the same individual, who is the owner of the building. Ato Tewodross Woldamlack (owner, contractor, a civil engineer and contractor) describes that, the main idea originated from the curiosity for the know-how for the potentials of vacant flat roof spaces on this building. According to the in-depth interview conducted with Ato Tewodross, he once have an assumption that , this unused vacant roof top spaces in his building can be used as a good resource to maximize the overall green area coverage of the overall compound. He also had, a good awareness on green areas huge holistic advantage for the resident (psychologically, economically, and environmentally). And there comes the need for the utilization of the additional vacant flat roof space (which most of the building in that neighborhood left vacant) for the use of double level green roof system.



*Figure 37* Top view of the cultivated extensive green roof consisting of edible plants .notice irrigation systems. Image source: site visit

### 4.1.5.2. Design phase

Since the owner is a civil engineer and also a contractor, he has some level of pre-knowledge of how to apply the intensive green roof system by utilizing the conventional materials as well as easily found local materials & vegetation's. The main plant types that are cultivated here are mainly composed of locally available edible vegetables. Residential level gardens need no sophisticated landscape design details; most clients with a little know-how can manage an entry level roof gardens. This is showcased by Ato Tewodrosses roof garden, by effectively designing

in consideration with conventional materials and plants to minimize application barriers that arise in the construction stage.



*Figure 38(view from the inside) of the cultivated extensive green roof consisting of edible plants .notice irrigation systems and plant types. Image source: site visit*

#### **4.1.5.3 Construction phase**

The green roof in this building is mainly separated into two separate levels (2<sup>nd</sup> and 3<sup>rd</sup> levels). Both green roofs are planted with edible plants such as potatoes, garlic, and spinaches.

##### **Section of layers:**

##### **2<sup>nd</sup> level green roof consists**

- Rc slab
- Xypex waterproofing
- Ceramic tile layer
- Soil layer (substrate)
- Vegetation layer (edible vegetables planted)

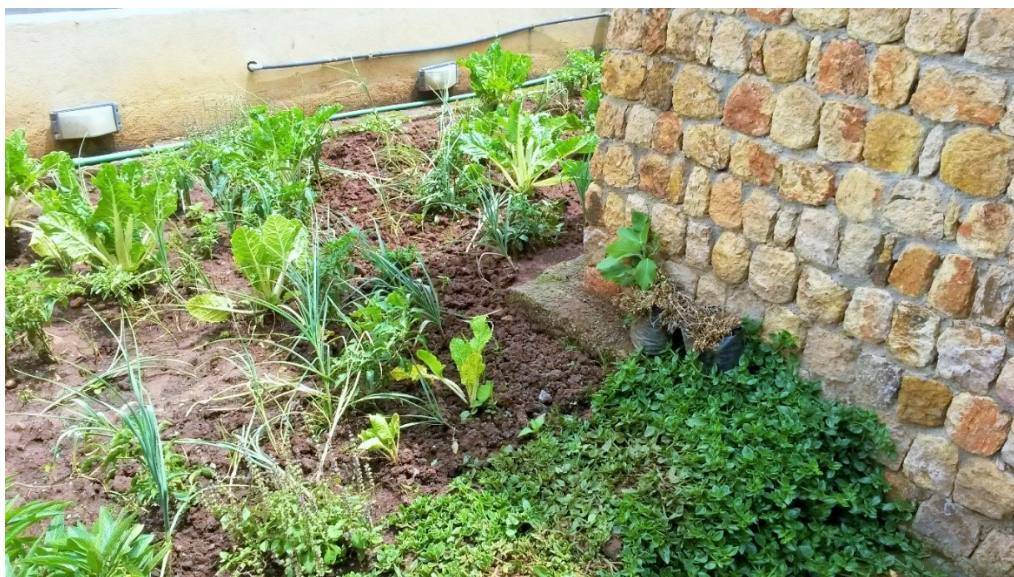
##### **3<sup>rd</sup> level green roof layers are made up of**

- Rc slab
- Xypex waterproofing
- Plastic sheet layer (to protect the waterproofing)
- Soil layer (substrate)
- Vegetation layer (edible vegetables planted)

Since the construction of the waterproofing's and other layers are made well with good workmanship and close supervision, there are almost no leakage issues faced during its lifetime



*Figure 39 Top view of the different floor green roofs with the cultivated extensive green roof consisting of edible plants .notice irrigation systems. Image source: site visit*



*Figure 40 Small scale urban green roof farming is achievable, this is demonstrated from by this example even with a help of a little motivation and inputs. Image source: site visit*

#### **4.1.5.4 Maintenance**

Since this building is a residential building, most of its pruning, watering, and other maintenance activities are overtaken by the owner himself. This scenario will create a proper landscape maintenance scheme with watchfulness since the owner is aware of how to prune accordingly without damaging the roof and what techniques should be taken as a result.

#### **4.1.5.5 Current condition**

Currently, this green roof is in good condition that there is no evident leaking up to now, the residents consume the products of this roof garden (grown vegetables) products for themselves.

This small urban roof garden shows that there is a huge capability to widespread the green roof system by creating awareness as well both on professionals and developers. Awareness creation and reducing the fear for the new technology can be very vital even in residential buildings.



*Figure 41 Successful urban green roof vegetable farming with locally available materials and construction techniques. Image source: site visit*



*Figure 42 View of the roof garden from inside 3rd floor creates an extended green surface even on the 3rd-floor roof top space. Image source: site visit*



*Figure 43 Unused vacant rooftop space on the same building, which can be used for further green roof expansion. Image source: site visit*

## 4.1.6 Discussion

From the assessments of these case studies, we can understand that the green roof system industry is at its early age in current condition of Addis Ababa. Most of its accompanying professions require a huge capacity building process to catalyze the wide spreading of the green roofs in the city. Eventually, this will help to create an environmentally resilient and sustainable green city.

It is clear that when we observe these case studies, we can simply understand that the challenges we are facing now in Addis Ababa are not new, since the developed countries passed through this stage throughout the previous years and they solved most of these problems effectively.

When we see international practices, such as the study of the (GSA) also demonstrates that “*The General Services Administration has designed and maintained green roofs for decades and finds them to be economical amenities that make fiscal and environmental sense. The GSA currently maintains at least 24 green roofs in 13 cities around the country. GSA routinely installs green roofs on new and existing buildings.*” (GSA, 2011), p.i.

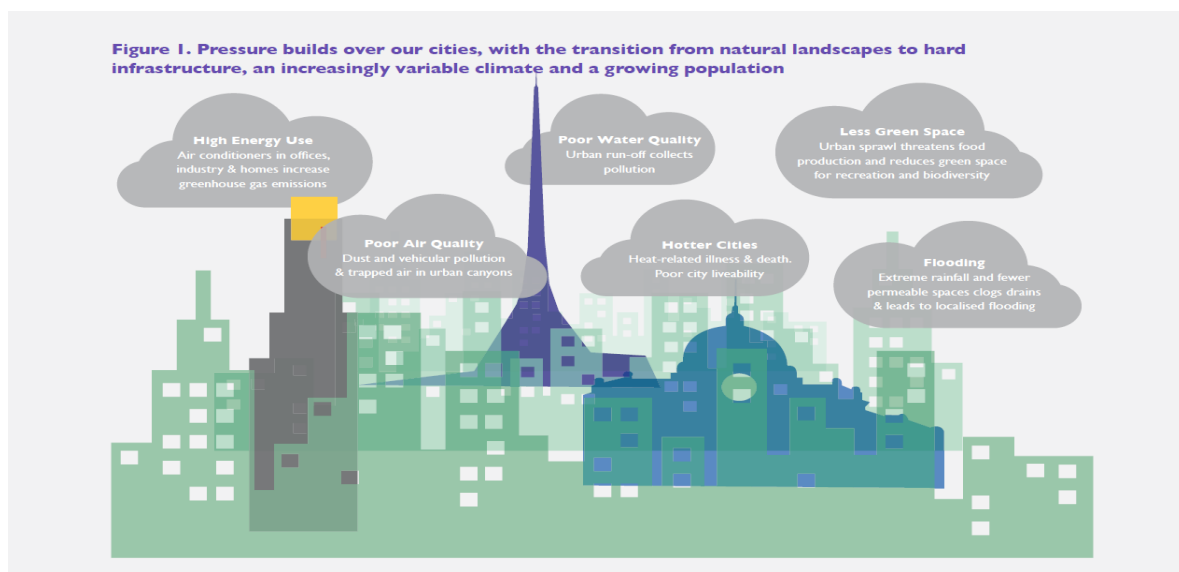


Figure 44 the current global cities environmental problems. Image source: (Growing Green Guide 2014)

As Jason Duda in his research entitled ‘Incentives and Barriers impacting the Implementation of Green Building Exteriors States that “*The lack of knowledge and education on green exteriors in Australia means that there are a limited number of consultants with expertise and experience in the design and construction*” (Duda, 2009). As we can see from this argument even at the international level including developed countries, there are several factors that are barrier to this system. As it costs more in the building process, many professionals afraid to take the risk. This is also true for Addis Ababa’s. The main challenge hindering the city’s green roof industry is that, most of the professions that are in charge for this green technology are either not willing to experiment or afraid to take a risk for a new type

of construction system. This can be because of several cost-related risks, or there is a shortage of skills, awareness, and education particularly on green building systems.

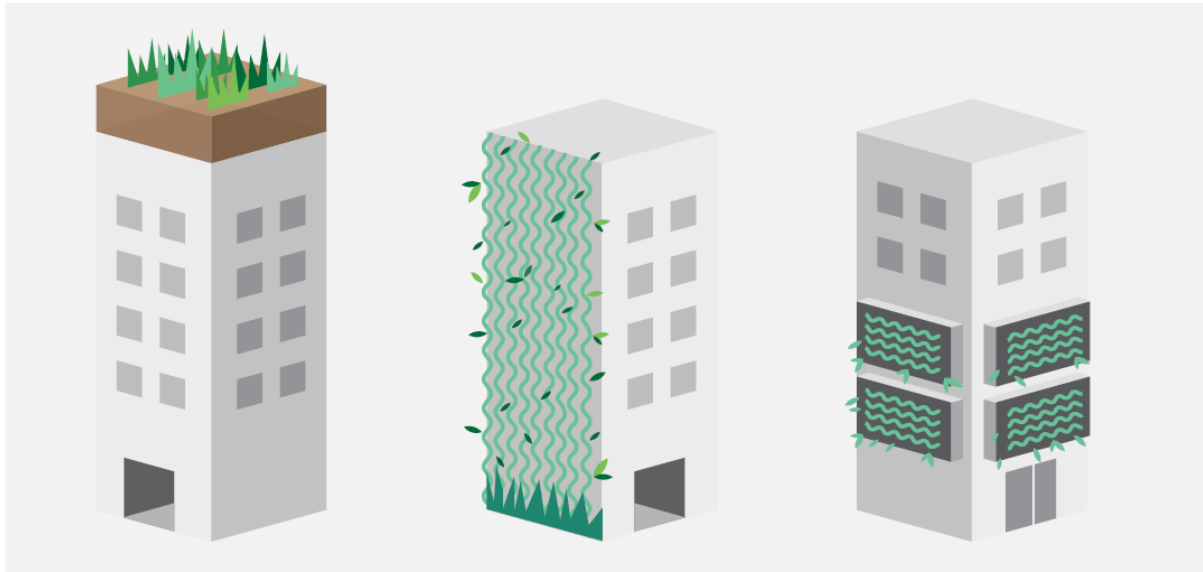


Figure 45 Alternative green building systems. Image source: (Growing Green Guide 2014)

In the meantime, these case studies portray green technologies can be achievable in the context of Addis Ababa with a little consideration and prioritization with the introduction of new construction methods and design approaches. Subsequently, most of the responsibility to widespread this technology is laid generally on the respective professionals, particularly on urban planners, architects, landscape architects, and contractors.

(Jason Duda) mentions a similar approach by explaining as follows “*Many urban land use planners would not have experience or expertise in understanding the impact of Green exteriors and may not know how to assess such a proposal. In lieu of a green exterior specialist, an alternative is to have a team of urban professionals assessing proposals. These may include town planner, landscape architect, ecologist, engineer, and urban designer.* (Duda, 2009). If enough awareness creation is made at a citywide level, then the respective professionals will be well informed and will be eager to experiment and try this new approach. Furthermore, they can highly influence and persuade the majority of the community as well as the government to accept this essential technology’s.

One of the main challenges in the developer’s side is the fear for the constant need for maintenance, because of landscape pruning and other related problems. This is also a challenge for many countries that are trying to adopt these green roof systems. As Jason Duda formerly comments “*One issue identified is what happens when buildings are abandoned and is unable to be properly maintained. Unlike conventional buildings where fenestrations can be boarded up if unoccupied or abandoned, green exteriors may pose risks for adjoining landowners or the greater community. Potential issues of increased fire risk, rodent breeding, the spread of weeds and potentially undesirable smells from rotting organic matter*” (Duda, 2009).

However, when we compare the general various holistic benefits and services that we gain from green roofs with the additional cost, in the long run it overweight the extra cost substantially.

The absence of a specialized green roof contractor is also other downside that challenges architects and consultants as they try to integrate green roofs to their building designs. As a result establishing and empowering a capable specialized green roof contractors is a must.

This can be achieved by having several incentives and supports. A good suggestion is mentioned in Jason's study as follows: *"There are two types of incentives from green exteriors, the first is implied, and benefits that are achieved if anyone developed a green exterior. For example, a green wall reducing the number of blank walls on a development hence less graffiti. The second is additional or supplementary, such as funding to develop green exteriors from local government"* (Duda, 2009). The availability of specialized plant nursery's that specifically focuses on particular vegetation's that are suitable for green roofs (such as succulent and sedum plants) must be readily available for the contractor to fill the overall gap.



Figure 46 Gheralta lodge Ethiopia, green-roofed buildings.



Figure 47 Hope university college library building green roof exterior view. Image source: site visit

## **4.1.7 Result-1 (Reflection on perspectives on interviews with implementers & professionals in the field.)**

### **4.1.7.1 Owner/Developer side barriers**

#### **Fear of new technology and system**

The fear for the introduction of new technologies on the developer side is the major barrier. Even in the residential buildings (that need extensive green roof layer), most of the developers hesitate to apply this new green building system for various reasons. One mentionable reason is the absence of enough successful pilot projects that can showcase the majority of the community and help to persuade developers. Successful pilot projects can portray that, this is achievable and it can be applied to their conventional buildings also with a little creative use of locally available materials.

#### **Cost and maintenance related issues.**

After interviewing Ato Wolde from the client side (Hope University), the installation and maintenance cost is inconsequential or negligible when compared to the various benefits of green roof. To mention some of the benefits, controlled stormwater management, urban biodiversity habitat, microclimate temperature regulation, psychological benefits, and aesthetical values are few them. A typical reason that developers think green roofs can be costly is, they consider them as a luxury or an extravagance. This comes from the lack of awareness knowledge of their benefits. These subject even encompasses the professionals including, the architects, landscape architects, contractors and government bodies.

#### **Huge vacant roof space available as a resource**

It is also obvious that in the current situation of the city, most of the buildings can support the extensive green roof systems that can support the advance of a sustainable green city. Bearing in mind this, the government should take the first step to create mandatory policies including green roofs within a portion of the available flat-roofed space. So that they can contribute or add to the overall green area surface coverage of the city.

Addis Ababa has a large number public and private buildings with substantial vacant flat roof spaces. One can assume this vacant rooftop spaces as a potential land resource. Even if we can utilize at least 50 percent area for green roof development; it could create a huge impact on the overall the city's environment and its respective services.

### **4.1.7.2 City administration/government level issues**

#### **Need for enforcement**

Even government officials should push and help properly for the introduction of alternative GI solutions such as green roofs, if city scale adaptation is needed. Currently, policy level green infrastructure introductions are found in government guidelines such as, in the Ethiopian

National Urban Green Infrastructure standard produced by the Ministry of Urban Development and Housing (MUDHo). However, if the government is well informed about its full potentials, the respective bodies can create mandatory regulations to apply green roofs in new building constructions. In conclusion, enforcement requires to be able to integrate green infrastructures in the development processes.



*Figure 48 View from street Hyatt Regency Hotel Project, ASB Hotel Properties PLC, green roof and balcony gardens (under construction)*



*Figure 49 Top view of Hyatt Regency Hotel Project, ASB Hotel Properties PLC, green roof and balcony gardens (under construction).*

### **Lack of incentives and detailed technical guidelines**

Local guidelines including the (MUDHo) guideline are very general. As a result, a detailed illustrative technical guidelines produced by the respective authority are mandatory. Incentives are also a crucial tool to encourage developers if city scale impact is needed.

## It could be an invaluable tool to preserve several indigenous plants

Since we are losing most of our indigenous and endemic plants; green roofs could be an invaluable resource for creating the habitat for these species. If we researched well on local drought resistant and impact resistant plants, it would be a significant addition in terms of sustainability and the overall longevity of the green roof. One good starting point could be the creation of an indigenous and green roof dictated plant nursery that can produce specific indigenous plants for the green roofs.

International studies and research's emphasize green roofs huge potential on the regeneration plant species in urban areas. Discussion paper prepared for Toronto City Planning entitled Using Green Roofs to Enhance Biodiversity in the City of Toronto also demonstrates that: *“Conceptually, green roofs can be viewed as a strategy to shift lower diversity habitats (Conventional bitumen roofs) into higher diversity ones (green roofs). Hough's (2004) Observations on terrestrial habitats, suggest a phased-in method to restore fuller diversity. He recommends starting with fast-growing pioneer plant species that provide initial ground cover, ameliorates existing soil damage, adds nitrogen and bacteria provide niches for fungi and create a variety of microclimates for other species to intercept. This would be followed by an intermediate phase where different plants are introduced and are followed by a climax phase (forest groves) where slow-growing, long-living perennials and trees become part of the established plant community (Anne & Bass, 2010).*

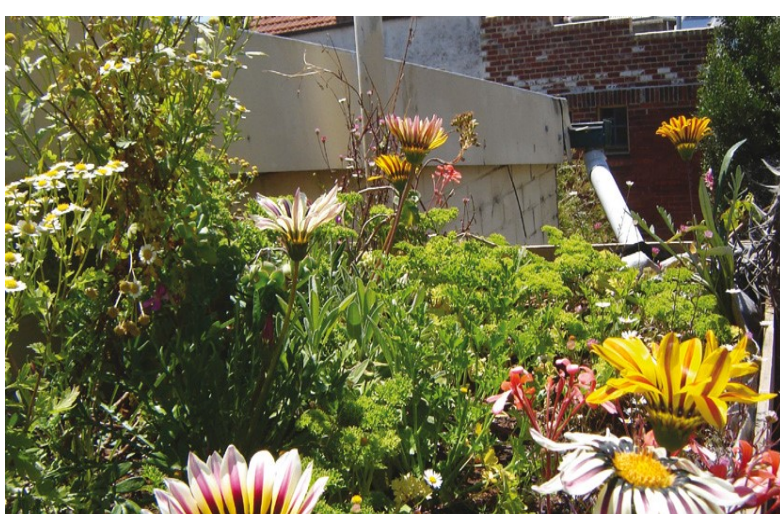


Figure 50 image source: *Growing Green Guide: A guide to green roofs, walls, and facades in Melbourne and Victoria, Australia*

### 4.1.7.3 Design level challenges

#### Professionals lack of awareness, and eagerness for the experiment

Building sector professionals such as architects, landscape architects, and others lack proper knowledge, practicality on alternative GI solutions such as green roofs. Subsequently, many of the disciplines tend to practice the usual and generic building designs with no environmental

considerations. However, basic green design approaches such as concept level green building technology should be practiced and researched well in the industry.

Other issues includes, is the lack for the capacity to produce a high-quality detail design having numerous connection details assisting the contractor. This issue also have its own impact on the needed quality of construction. This problem mainly comes with the absence on the exposure and practice with international level projects and as a same time with a lack of workshops that can serve as a good knowledge exchange platform in the design and construction of green buildings.

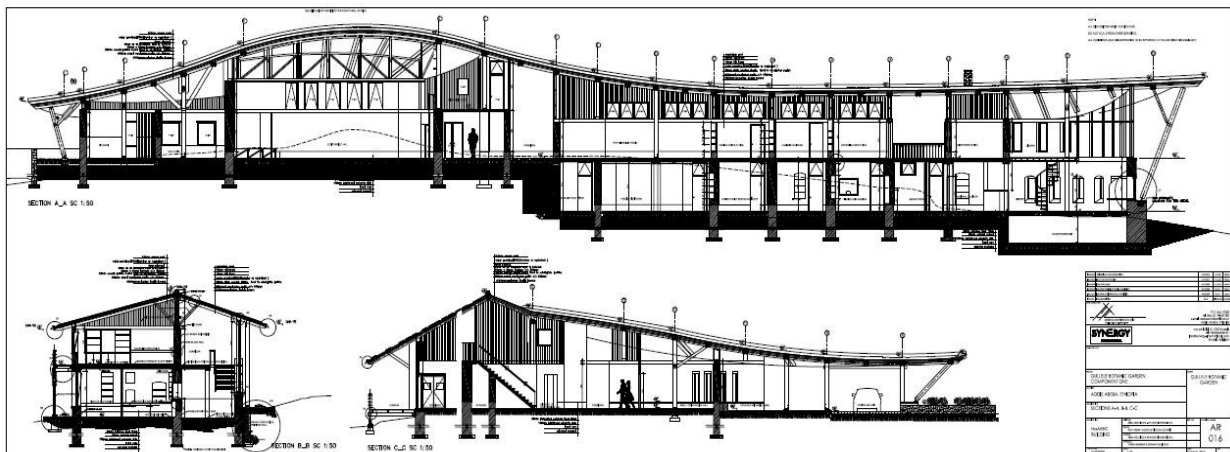


Figure 51 Section drawing showing the Gulele HOAREC building with its green roof, Image source: ABBA Architects plc.

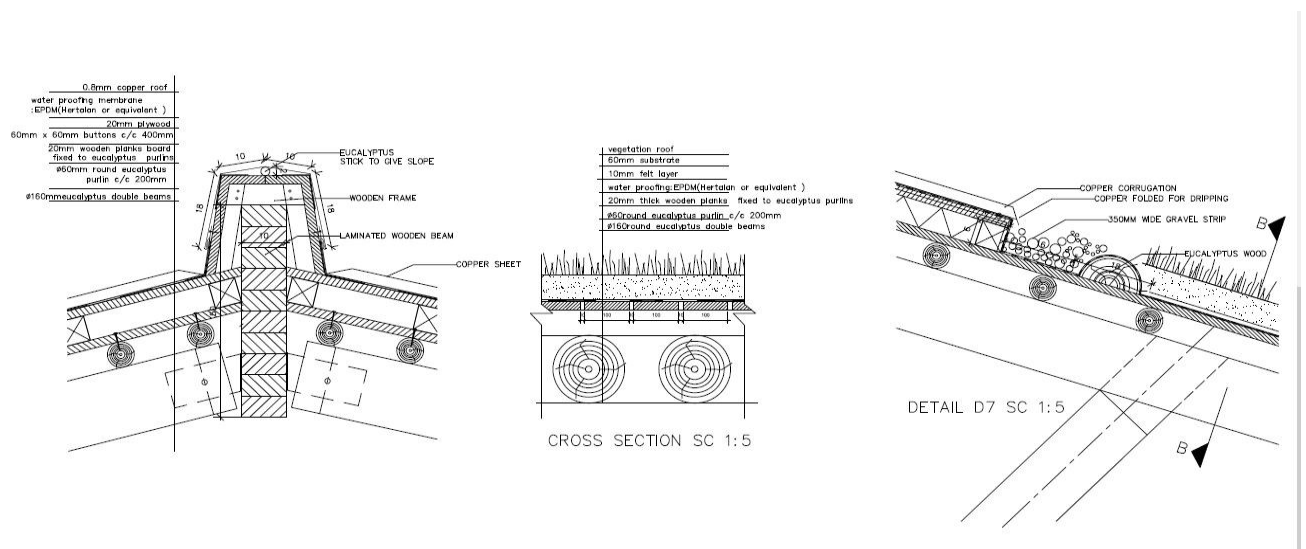


Figure 52 Section drawing, showing various construction details of the green roof of the gulele HOAREC building. Source: ABBA architects plc.

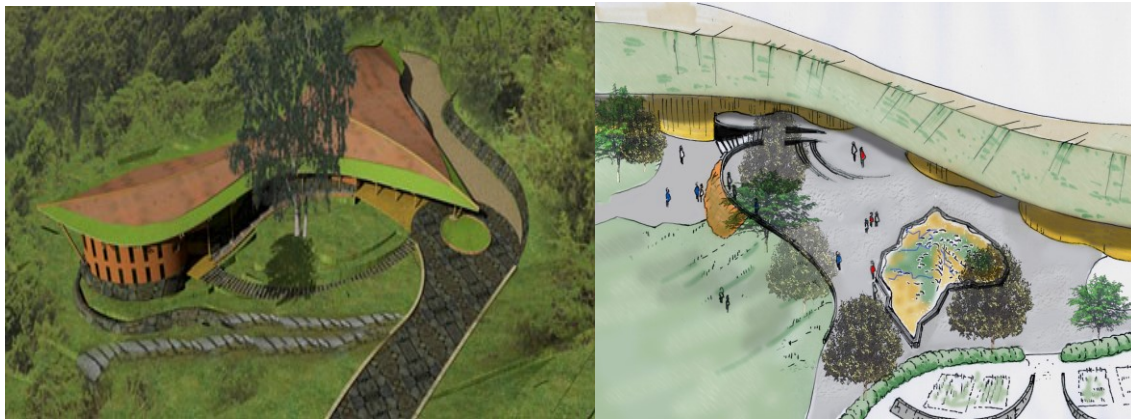


Figure 53 Gulele Botanic Garden Center Extensive green roof design.



Figure 54 Exterior photo of Gulele Botanic Garden Center Extensive green roof after construction.

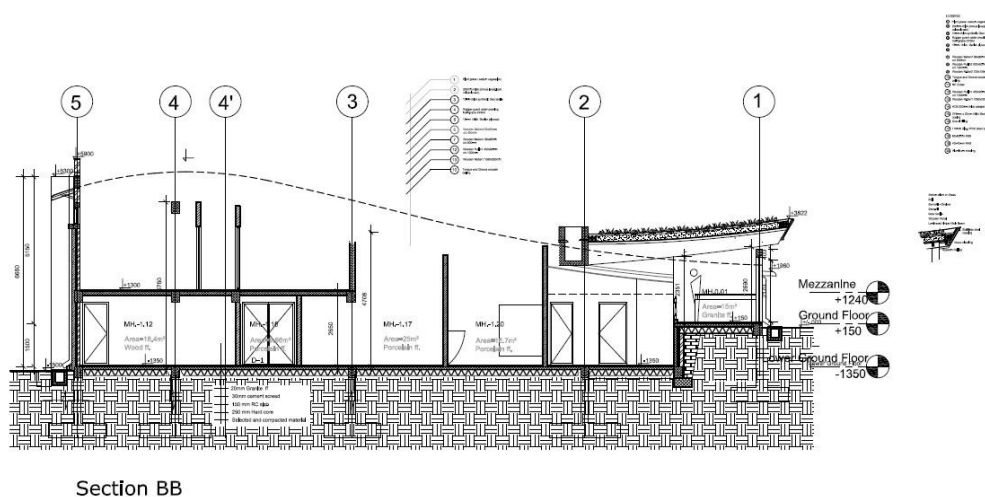


Figure 55 Section drawings, showing various construction details on the green roof of the Gulele HOAREC building. Source: ABBA architects plc

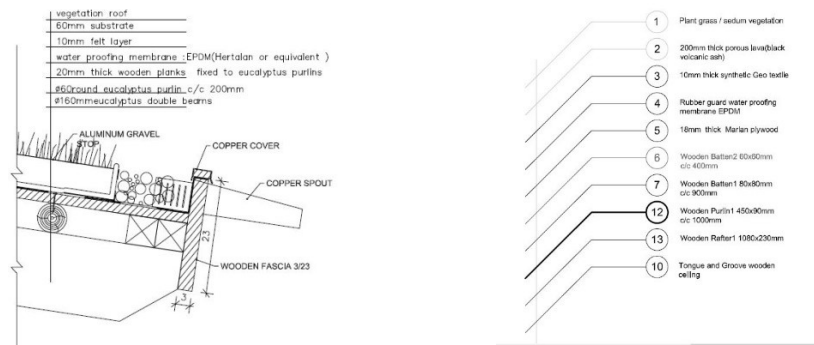


Figure 56 Section drawings, showing various construction details on the green roof of the Gulele HOAREC building with its green roof. Source: ABBA architects plc.

## A huge resource of cumulated practices & lessons from international experiments

Since many successful green projects are undertaken in western and Asian countries, there is an invaluable resource to create a customized design & construction solutions. In the meantime when learning from the mistakes of other developed countries, we can avoid unnecessary expenses and wastages by avoiding a trial and errors construction approaches.

### 4.1.7.4 Construction level challenge

#### The Absence of a specialized green roof contractor.

The Absence of a specialized green roof contractor is a major challenge in this sector. Furthermore, Most of the landscape contractors are not informed well about the special plants that are particularly appropriate for green roofs, which are dry weather and harsh sun resistant plants. The absence of specialized plant nursery of green roof plants is another factor affecting the contractor's capability on the supply of materials. This will results to unwanted plants to be planted on the roofs. As Ato Yoseph (architect, ABBA) mentioned in the interview, one of the challenges he faced on the Gulele Botanical Garden green roof project was, the lack of awareness and know-how on the specific types of plants with the respective contractor handling the project.

#### The absence of appropriate crane system, access, and logistics

Particularly when applying a green roof in existing building, the issue of organized logistics is a concern. For the reason that the transportation of soils and other materials and the maintenance process through the internal staircase might interfere with the daily life of the residents, unnecessary interior pollution in the building will be there through the process. On the contrary, if we can use external access or other means, it will solve this problem. Special crane systems are also desirable in the construction process, since the nature of the construction features need a close lookout. Especially soft scape moving machines will help the worker to easily move in the green roof without damaging plants and other elements.

## **Workmanship**

Since workmanship quality is associated with all construction sectors, the same rule applies here. Particularly the application of waterproofing and some special details need close supervision and good workmanship. On the current situation of Addis Ababa, empowering skilled laborers and specialized construction contractors must be considered as mandatory.

## **Maintenance level issues**

The maintenance phase is the other area of challenge, this is because of a couple of reasons. As the interview with Ato Yoseph from ABBA architects revealed, the absence of awareness on how to skillfully dig and prune on the constructed green roof is a key issue. Ato Yoseph mentioned this challenge by mentioning one example that faced a challenge during the maintenance process, the hope university library building faced significant problems because of the unaware laborers digging and patching the waterproofing under the substrate (unintentionally). This creates weak spots that creates a loophole for water to leak to the building. This can be solved by educating the laborers on proper techniques.

### **4.7.8 Summary**

Major challenges identified are, the absence of a detailed prototype design manual for major types of roofs in Addis, the absence of specialized green roof contractor, the deficiency of a specialized plant nursery's as well as the lack of proper and mandatory policies on alternative green infrastructure solutions such as green roofs. After the interview, it becomes clear that the awareness problem is the most significant barrier. The lack awareness both on the developer and within the professionals can be taken as a major obstacle for widespread of this new technology. Even in some developed countries, the awareness problem on introducing alternative solutions into the urban landscape is still challenging. Almost all of the mentioned challenges in the interview could be avoided or minimized with a subtle focus on government and on the respective professionals. The rest will eventually flourish within the process when the respective stakeholders play their role respectively. This was also demonstrated in various international practices and projects such as that are mentioned on literature review. Furthermore, it is clear that building owners could be very optimistic if there are a series of successful pilot green roof projects undertaken by the government to showcase green roof applications, and conveniences as an awareness creating tool.

## **4.2 Result-2 (Green roof design guidelines & Customized modular green roof designs)**

### **4.2.1 Design and guideline description.**

After referring the above international practices which are mentioned in section 2.6, a prototype green roof design manual is prepared as a design recommendation for the context of Addis Ababa. This design manual tries to use locally available and affordable materials that the middle-class developers, and as well as the contractors can afford and access easily. Most of the sample techniques are examples of creative approaches for experimenting in local adaptations of green roofs.

This design manual tries to address commercial developers as well as individuals living in a mass housings (condominiums and apartments). In the preparation of this manual, it is attempted to refer international case studies and experiences on modular green roof system practices. Afterward, it is attempted to substitute the generic patented modular system with locally available materials, which are mainly locally found substrate holding containers.

These containers can be produced using local industries. Even some of them are constructed using recycled plastic materials that are collected from Addis Ababa's waste market. This will eventually help to utilize, environmentally friendly and sustainable raw material source. The second alternative containers are made from used wooden vegetable boxes, which are collected from Addis Ababa largest vegetable market "Atikilt tera". Since wood is decomposable material by its nature, and as well as the boxes will be collected from the used market, it will make them an environmentally friendly alternative. The third alternative is a conventional planters with a specially designed supporting frame system for holding several planters at the same time in the balcony. This in the long run maximizes the green coverage on the exterior of the condominiums.

The other advantage of these modular green roof systems is their portability. Due to their modular design, developers and contractor can easily remove and relocate them during installation and in plan changes. The last section of the manual demonstrates sourcing skills, needed expertise, and related information's for green roofs development. This will give an overview of the needed professional and expertise on developing GR systems. Finally, the manual finishes with the recommendations on sample indigenous and exotic plants species for the green roofs considering the weather and altitude of Addis Ababa.

## 4.2.1 The customized modular green roof designs.

### THE CUSTOMIZED APPLICATION OF GREEN ROOFS FOR ADDIS

2018

#### THE DESIGN

- Major green roof Socio Economic Benefits:  
The key socio economic benefits of roof gardens and green roofs are:
- Recreational and garden use for the inhabitants
  - Potential for improving urban food security.
  - Improved Aesthetics and quality of life for the residents of the city.
  - optimized outdoor indoor acoustics.
  - Energy conservation (minimizing artificial air conditioning cost).
  - creating a Good opportunity for urban agriculture & Job generation



A typical flat roof space in addis buildings  
:Source- <http://www.timilix.com>



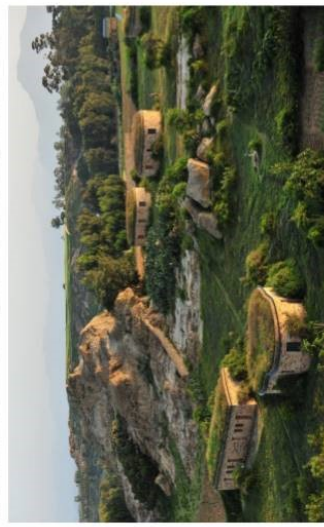
palm guest house addis terrace :Source- <https://www.booking.com>



One of addis ababas potential roff top terraces cafes :Source- <http://addisababaonline.com>



North addis hotel in addis terrace :Source- <https://www.booking.com>



MASTERS OF LANDSCAPE ARCHITECTURE

DONE BY MARKOS FEKADESELASSIE

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THE CUSTOMIZED APPLICATION OF GREEN ROOFS FOR ADDIS

M-TRAY MODULAR GREEN ROOF SYSTEM



Wallbarn has many years of experience in landscaping and green roofing technologies. We are constantly innovating and developing new products and techniques to improve and enhance rooftop living.

WHY MODULAR?

The main advantages of modular over roll-out green roof systems include convenience and speed of installation, futureproofing, and the delivery of instant results.

All the elements required for a successful green roof have been measured and installed into the M-Tray® modules at the nursery. Users can feel confident that the plants, growing medium and filtration components are suitable and compatible, and at the correct level to give strong, healthy growth over the long term. The trays are grown for a period of at least 6 months and all will have been through at least one spring growing season, so the plants are well established, healthy and strong, and fully integrated into the substrate (unlike sedum blankets, which are not).

Speed is also a major factor. It has been proven that green roofs constructed using Wallbarn M-Tray® are installed much faster than in traditional roll-out methods.

It is also an instant green roof. Since the sedum are less shocked by the installation process, as soon as the trays are connected together the whole area is filled with well-established plants. They will start to grow straight away, forming a seamless layer of vegetation much faster.

Access to the roof is future-proofed. If there are problems with the deck beneath or inspection is required, one M-Tray® or section can easily be lifted out without disruption to the whole roof.



Green roofs are very adaptable and can be designed for large or small areas on most structural decks. However, truly understanding the horticultural requirements of introducing vegetation onto artificial surfaces is a discipline which requires specialist skills and knowledge. All green roofs need light, water, drainage, and correctly engineered soils. Without ALL of these elements the green roof vegetation will not thrive. Wallbarn green roof systems are constructed in order to provide sustainable long term vegetation and to minimise maintenance.

Image and text source - [www.wallbarn.com](http://www.wallbarn.com)

MASTERS OF LANDSCAPE ARCHITECTURE

DONE BY MARKOS FEKADESELASSIE

MODULAR GREEN ROOF (CASE STUDY)

2018



Key advantages

SMOOTH EDGES & CONNECTING BRACKET

TRIMS & EDGING

100mm aluminium edge trims and connectors fit neatly onto the sides of the modules. Fixings are designed to slot together neatly although they are not always necessary.

STEP BY STEP INSTALLATION

M-Tray® modules will be transported to site shrink wrapped on pallets for easy, clean delivery. They can be craned safely onto the roof if necessary. Each module is 500 x 500 x 100mm, so exactly 4 units make up one square metre.

Unpacking the pallets is a simple process. None of the contents will spill out and each module can be carried by one person without disruption. A separation and filtration geotextile layer should be firstly installed onto the deck. This protects the waterproofing and prevents abrasive damage.

Start from the middle of the green roof and work outwards towards the edges. Place a module down and then click the next into place. There are two connection points on two sides of each module. Once connected up on all four sides, the module will be fully secured.

Image and text source - [www.wallbarn.com](http://www.wallbarn.com)



The modular green roof panels are packaged and delivered in the most convenient manner.



The modular green roof panels are packaged and delivered in the most convenient manner.



The speed and ease of installation is illustrated very well in the images shown here.



Image and text source - [www.wallbarn.com](http://www.wallbarn.com)



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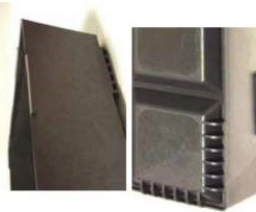
THE CUSTOMIZED APPLICATION OF GREEN ROOFS FOR ADDIS

2018 MODULAR GREEN ROOF (CASE STUDY)



THE DESIGN

The module measures 500 x 500 x 100mm. As four units make up exactly one square metre estimating is a far easier process. There are less drainage holes than in previous versions to keep water within the green roof system for longer. This allows the plants to absorb more rainfall, increasing attenuation and delaying discharge into outlets. The edges of the module do not have drainage holes in order to prevent the sedimenting back at the edges. Stronger plant growth at the edges creates a more seamless layer of vegetation when the modules are connected. Four gently ridged hand grips are positioned to enable installers to carry each module easier.



TECHNICAL DATA

PRODUCT	M-TRAY® MODULAR GREEN ROOF CONTAINER
SUITABLE FOR	PERMANENT OR TEMPORARY PLANTS WITH LIGHTWEIGHT, PERMANENT SUBSTRATE
TYPE OF CONSTRUCTION	PERMANENT
WIDTH / BREADTH	500MM X 500MM
HEIGHT	100MM
SHAPE OF WALLS / SIDES	TAPERED / ANGLED
UNITS PER M2	4
MATERIAL	RECYCLED POLYPROPYLENE
THICKNESS OF MATERIAL	3MM
INTERNAL RIDGE HEIGHT / RESERVOIR HEIGHT	20MM
NUMBER OF INTERNAL DRAINAGE RESERVOIRS	25
DRAINAGE HOLES PER UNIT	8
DISTANCE BETWEEN TRAYS AT BASE	20MM
DISTANCE BETWEEN TRAYS AT 50MM FROM BASE	10MM
DRY WEIGHT (EMPTY)	1.1KG
WEIGHT PLANTED & SATURATED	2.4KG
CONNECTORS PER UNIT	4
NUMBER OF HANDLES ON UNDERSIDE	4
DETAIL OF CORNERS / EDGES	SMOOTH / REINFORCED
EU DESIGN TRADEMARK	NO 002953943-0001
US DESIGN TRADEMARK	NO 29/955,129
<p>® BASED ON FILLS WITH WALLBARN PRODUCED &amp; APPROVED LIGHTWEIGHT, EXTENSIVE GREEN ROOF SUBSTRATE FULLY PLANTED WITH NATIVE SCUM PLANTS TO RECOMMENDED COVERAGE AND SATURATION.</p>	

KEY ADVANTAGES

The advances made in the design of the new M-TRAY® model include:

- deeper cavities for extra root growth
- optimum drainage leading to stronger plant growth
- more established vegetation at point of installation
- more efficient transport and packaging
- exactly 4 units per m<sup>2</sup>
- easier to carry trays with smooth handles
- closer connection between trays for more seamless plant growth
- no sharp edges, less risk to the membrane
- nothing spills out, less mess
- made from recycled plastic with recycled substrate
- less packaging, less waste
- UK designed and manufactured in UK



All image and text source - [www.wallbarn.com](http://www.wallbarn.com)



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THE DESIGN



Huge resource for recycling plastics:  
Source- <http://www.gettyimages.com>



MERCATO PLASTIC USED AND NEW ITEMS :Source- [www.awl-images.com](http://www.awl-images.com)



Locally available cheap plastic holders that can be used for modular green roof.  
Source- <http://www.skyindustrieset.com/>



locally available plastic items



locally available washing plastics- source: [truedays.net](http://truedays.net)



available flower boxes- [wccr2011.org](http://wccr2011.org)



available flower boxes- [thriftyfun.com](http://thriftyfun.com)



sample nurseries (selam childrens village) source <http://ouruppellee.blogspot.com/>

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**EiABC**  
Ethiopian Institute of Architecture, Building and Construction  
Ethiopian Institute of Architecture, Building and Construction  
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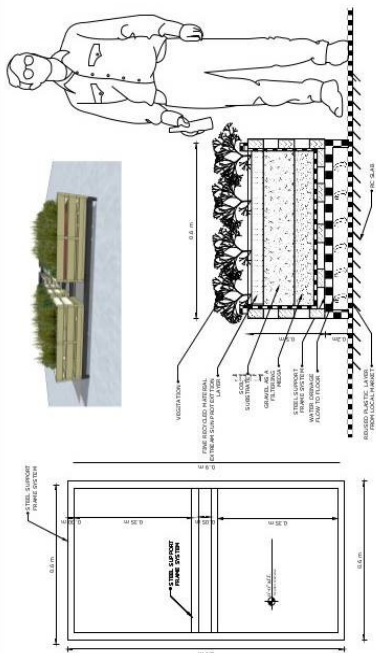
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 Email: info@eiabc.gov.et

THE CUSTOMIZED APPLICATION OF GREEN ROOFS FOR ADDIS

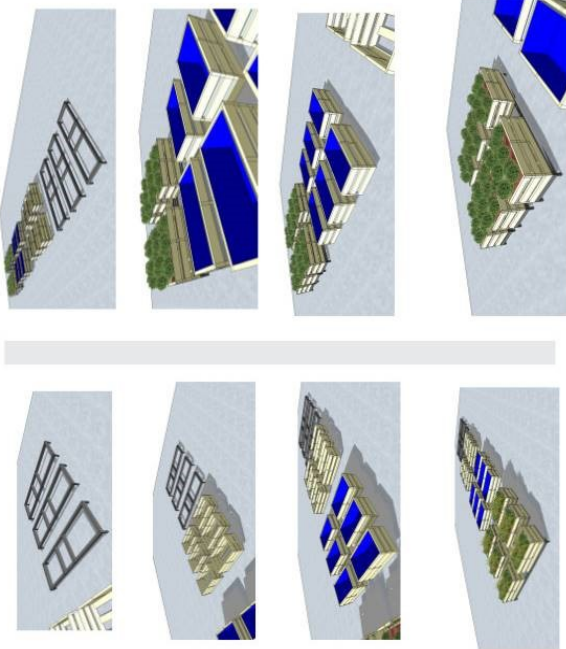
2018

LOCALLY AVAILABLE VEGETABLE BOX AS A GREEN ROOF PLANTER

CASE STUDY



PLANT BOX FOR ADDIS ABABA GREEN ROOF FROM RECYCLED MATERIAL



Used Wood boxes as recycled planter source: TERNAESTE



A rooftop garden that utilizes recycled material source: gettyimages.com



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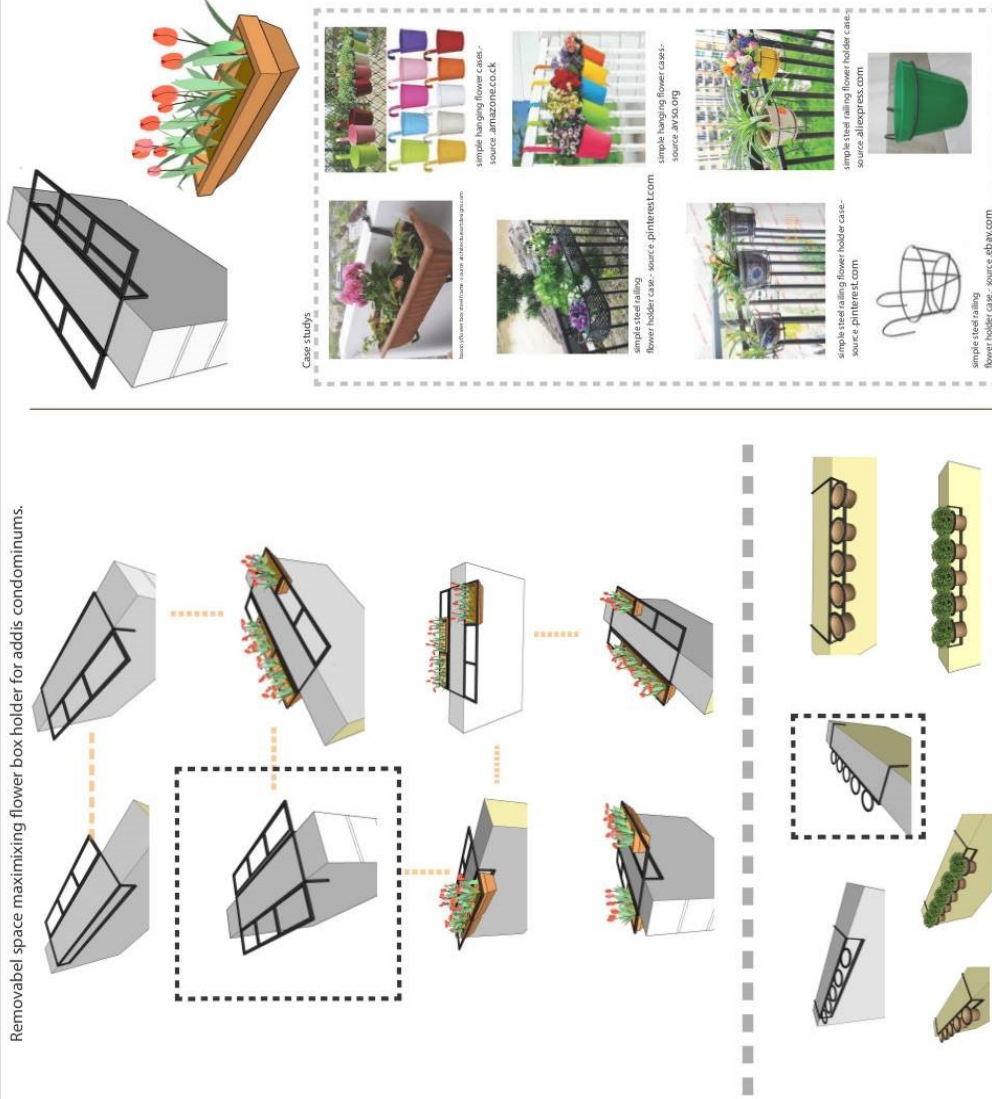
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 www.eiabc.com

THE CUSTOMIZED APPLICATION OF GREEN ROOFS FOR ADDIS

2018

Removable space maximizing flower box holder for addis condominiums.



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### Sourcing skills, expertise and information

- Project manager**
  - Develops a project timeline
  - Manages construction budget and payments
  - Ensures contractors have appropriate registration, licensing, insurance and working at heights training
  - Manages site inductions for all personnel
- Construction manager / Principal contractor**
  - Plans and oversees construction activities
  - Engages contractors, or sub-contractors.
- Architect or landscape architect**
  - Designs the project, working with the client to select the most appropriate system for the site, including consideration of how it will be managed and maintained in the long term
  - Coordinates planning and building permits, either directly or through a building surveyor
  - Reviews progress and inspects construction
  - Provides advice on the installation in the context of the whole site/landscape
- Leak detection specialist**
  - Carries out leak testing at specified stages of construction, and as part of regular scheduled maintenance
- Horticulturalist**
  - Provides advice on growing substrate
  - Recommends and sources suitable plants
  - Seeks specialist advice (for example, arboricultural advice for tree selection)
  - Coordinates delivery and installation of plant materials
- Green roof provider**
  - Provides design advice to architect/landscape architect (or may undertake all design work in a small project)
  - Provides advice on all elements required for the green roof build
  - Supplies and installs all green roof elements, usually including growing substrate and plant materials
  - May provide advice on maintenance and long-term management requirements

- Irrigation consultant / Hydraulic**
  - Advises on a suitable irrigation system during the design process based on the proposed substrate depth/volume and water-holding properties
  - Advises on use of recycled/harvested water, pumps, and storage tank volumes and configurations
  - Advises on approaches to sustainable and efficient water management in the context of the whole site (water sensitive urban design)
  - Advises on integration of the irrigation system with the rest of the building's water system
- Landscaper manager / Maintenance manager**
  - Oversees maintenance contractors
  - Negotiates and manages contractual arrangements
  - Allocates budget and resources to maintenance activities

- Builder**
  - Constructs the building, or installs any structural reinforcement needed in a retrofit green roof project
  - Installs any built-in elements associated with the roof, wall or facade, often in conjunction with the green roof, wall or facade provider
- Building surveyor**
  - Reviews and approves building plans
  - Reviews construction for compliance with the regulations
  - Arranges for Building Permits and Occupancy Permits with local councils

- Waterproofing supplier and contractor**
  - Reports on the condition of the existing roof (retrofit), and recommends the most suitable waterproofing for the project
  - Prepares the roof and installs waterproofing

**SOURCE- GROWING GREEN GUIDE**  
 A guide to GREEN roofs, walls and facades  
 Melbourne and Victoria, Australia

### GUIDELINES

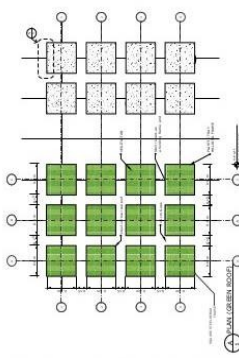
#### Designing for maintenance

The architect or the landscape architect must be clear about maintenance objectives and their capacity to undertake them with locally available resources. The architect must consider maintenance process and costs in design process of the green roof.

This includes the maintenance costs since it is an important part of the design considerations, especially for the owner.

Cost of logistics shall be considered since it may be needed for renewal or removal of a green roof, where it temporarily needed

#### ALTERNATIVE G-R SOLUTIONS : MODULAR GREEN ROOF SYSTEM



A customized prototype modular green roof system that can easily be constructed with locally available materials is a mandatory to achieve a massive city scale adaptation of green roof system.

This will help to explore and try several combinations of modular green roof system for various types of buildings.

Gradually building developers and contractors will have a convenient way to easily apply these removable localized green roof system without further complications.



**SOURCE- GROWING GREEN GUIDE**  
 A guide to GREEN roofs, walls and facades  
 Melbourne and Victoria, Australia

### Drainage and irrigation considerations

- The water demand for the green roof can be known by creating annual water irrigation demand in volumes. this includes-
  - Calculating total water demand using various seasons of Addis Ababa
  - Calculating water evaporation rate during several seasons
  - Analysis of actual rainfall in various seasons.
  - The capability of the soil or the various substrate layers to withhold the Storm water.



### Urban food production considerations

- The main question raised on green roof food production is its proper accessibility for harvesting process other considerations include-
  - The structural load-bearing capability to support the harvesting process including various tools, persons and the needed substrate layers that will support the vegetables.
  - It is also necessary to evaluate the produced vegetables or other foods are not polluted or contaminated from pollutants in the air including excessive carbon dioxide.
  - Corresponding an environmentally sustainable water use is a good way to achieve sustainability of the green roof system.
  - Since food-producing plants usually have a tendency to Require a lot of water than a other non-food producing plants, it is essential to efficiently use that rainwater that is collected to reuse to irrigate urban green roof food production areas.

It also essential to consider the nutrient management system since Every crop harvest takes out the Nutrients from the substrate during the food production, therefore it is mandatory to keep adequate content of nutrients for further production.

### COST CONSIDERATIONS

- General green roof construction costs will differ due to the following factors:
  - The type of the slab or structure capability since some structures need additional reinforcement
  - The location of the site, logistics accessibility, the size of the green roof and the ease of access
  - The proximity for transport of materials.
  - The existence of work minimizing cranes this helps to easily move construction materials to the green roof.
  - Roof height, dimensions and load-bearing capacity.
  - The green roof design and construction complexity.
  - The overall project construction time containing the time spent for growing of plants.



# Chapter 5

## Conclusion and recommendations

The results of this study furthermore revealed that, the absence of clear implementation laws and policies mainly focusing on the government are the central problem. The Ethiopian National Urban Green Infrastructure standard, which is produced by the Ministry of Urban Development and Housing is a decent start. However, it lacks several detail technical guidelines and mandatory strategies. Since the government role is invaluable for the preparation of further detailed guidelines, incentives and the technical support platforms are very helpful to aid developers and other professionals to achieve a city scale adaptation of green roofs. One could easily understand that a holistic approach should be used to solve these numerous barriers. In order to tackle these obstacles at the grass root level, it must be started with the challenges that are encompassing the design and construction professionals.

If our aim is to create a city level interconnected link of green roof surfaces, there should be city scale training and awareness creation platforms prepared for the respective professionals and developers. The reason behind the need of a holistic approach is, it hard to bring a city level change by struggles of a specific professionals (for example the architects). This may lead to a communication and a knowledge gap within various professionals. In the meantime, consultants and design professionals are facing challenges particularly in finding an appropriate green roof contractor with a decent experience. Pioneering consulting firms that relatively practiced green roof designs & supervision in Addis Ababa (such as ABBA architects), faced various challenges that are mentioned before. However, they can be a great example for other local consultants on how to experiment on green roofs and similar solutions through overcoming the existing challenges.

Mostly, the availability of a proper localized prototype green roof manual that can be easily be applied by developers & building designers is mandatory. This gradually helps and encourages consultants and investors to easily apply green roofs with the available local materials and techniques. Even the developed countries faced several challenges in regard to adapt these alternative green roof systems into their cities. In the long run, they managed to come up with various approaches and solutions to aid developers & professionals with major types of supporting backings similar to the mentioned of incentives, technical manuals, and aids.

## 5.1 Recommendations

### 5.1.1 Addressing the respective stakeholders (City Administration, Developers, Consultants & Contractors)

- **Incentives** - Since developers in this new green building technology face several challenges, the government should give the appropriate incentives such as, allowing the contractors to import tax-free the needed green roof construction materials. This mainly includes special waterproofing's and similar accessories. This eventually will help contractors to experiment on these projects effortlessly. Long term incentives include, creating a system for funding developers who build green roofs especially by the government to compensate the ecosystem services that they provide.
- **Planning and regulation** - Additional necessary action that should be taken by the government is, making green roofs mandatory and enforcing the developers so that they include green roofs on large commercial and public building projects. Future preparation of strategies & proper and detailed technical guidelines by the Ministry of Urban Development and Housing (MUDHo) is also mandatory.
- **Consultants and Designers**- Since the lack of awareness and the absence of eagerness in green roof systems is the major issue in national level, awareness creation events on alternative green building techniques such as roof garden systems should be an urgent matter for architects/landscape architects and consultants. Pioneering and relatively successful consultants such as Abba architects can be also a good example as a local forerunner consultant for further awareness creation.
- **Construction sector** - According to the findings of this research, it is obvious that challenges facing contractors should be addressed well if qualified green roof contractors are needed to evolve in cities construction industry. As previously mentioned, again specialized plant nurseries that provide proper plant types for green roof environment will be a huge support for contractors to undertake any type green roof design. Contractors should be well informed about these new green building systems and their construction system by creating several awareness creation events that serve as a knowledge exchange event. Finally, incentives could be a vital tool for the government to encourage contractors undertaking this type of special projects such as by allowing tax free importation of the necessary materials and equipment's.
- **Developers / Owners** - Works also should be done on creating awareness in public and private building developers by the means of constructing successful sample pilot projects to demonstrate the potentials of this green building systems. Particularly, public projects can use the green rooftop space to generate money by creating an attractive roof space for cafeterias, game zones, urban agriculture, recreational areas, and other income generating programs. Furthermore, Spontaneous awareness creation events such as events that are focusing on elementary and high school students might be a game changer to raise awareness regarding green building systems. Technical supports should be given to

residential building developers to encourage them to widespread these green roofs in the city extensively.

### **5.1.2 Prototype modular green roof design manual**

The Preparation of a prototype detail design manuals considering the basic roof architectures of buildings found in Addis will be a vital tool for consultants and individual developers. As a result of this, they can easily incorporate these prototype designs into their designs. The detail design guides could be prepared by the respective institutions as well as universities focusing in this systems (such as EIABC and other governmental institutions).

Additional actions that could help consultants and landscape architects is, practicing abroad particularly on green roof projects so that they can grasp the technical and detail design techniques that are mandatory. This can be achieved well if various abroad knowledge exchange platforms are organized by government or the Association of Ethiopian Architects. In the long run, they could come up with customized techniques and solutions for Addis Abbas context.

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