T. R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF LANDSCAPE ARCHITECTURE

# INVESTIGATION OF THE ROOF AND VERTICAL GREEN STRUCTURES AND A SAMPLE APPLICATION TO ERBIL

M.Sc. THESIS

PREPARED BY: Darbaz Pirot MANKURI
SUPERVISOR: Assoc.Prof. Dr. Onur ŞATIR

VAN-2018

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**ACCEPTANCE and APPROVAL PAGE**

This thesis entitled **"Utilization Of *Chlorella* And *Daphnia* As Natural Food Sources And Their Combination As A Feed Supplement Compared To Commercial Feed For Common Carp (*Cyprinus Carpio*)"** presented by Amanj Ibrahim BAIZ under supervision of Asst. Prof. Dr. Ş. Şenol PARUĞ in the Faculty of Fisheries has been accepted as a M. Sc. thesis according to Legislations of Graduate Higher Education on 14.05.2018 with unanimity / ~~majority~~ of votes members of jury.

Chair: Prof. Dr. Mahmut ELP Signature:

Member: Prof. Dr. Fazıl ŞEN Signature:

Member: Asst. Prof. Dr. Ş. Şenol PARUĞ Signature:

This thesis has been approved by the committee of The Institute of Natural and Applied Science on 18/05/2018 with decision number 2018/25-I

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# THESIS STATEMENT

All information presented in the thesis were obtained according to the ethical behaviour and academic rules frame. And also, all kinds of statement and source of information that does not belong to me in this work prepared in accordance with the rules of theses, were cited to the source of information absolutely.

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## ABSTRACT

**INVESTIGATION OF THE ROOF AND VERTICAL GREEN STRUCTURES AND A SAMPLE APPLICATION TO ERBIL**

MANKURI, Darbaz Pirot
M.Sc. Thesis, Landscape Architecture Department
Supervisor: Assoc.Prof. Dr. Onur ŞATIR
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Urban development is causing environmental and social worries that are makes a risk to human welfare and the sustainability of cities. The new green architecture concepts are being developed to decrease problems by a sustainable and natural way. Roof and vertical greening systems can be defined as structures that allow vegetation to spread over a building or facade or interior wall. These systems are becoming popular with evolving slowly, and acknowledgement on some of their special impacts is required. In the last five years, the number of studies published in the scientific literature on this topic, especially involving living roof and living walls, has significantly increased. This scientific interest has corresponded with an increased and parallel attention by the general public. This scientific interest has agreed with an increased and parallel attention by the general public. This work offers a broad description of the different systems and a thorough review of the special benefits of these green infrastructures. Additionally, this study was designed a sample simulation to a part of Erbil city on living roofs and vertical gardens.

**Keywords:** Bio mimicry, Built environments, Energy conservation, Green roof, Living walls, Sustainable construction, Urban ecology, Urban greening.

# ÖZET

## ÇATI VE DİKEY YEŞİL YAPILARIN İNCELENMESİ VE ERBİL'E ÖRNEK BİR UYGULAMA

MANKURI, Darbaz Pirot
Yüksek Lisans Tezi, Peyzaj Mimarlığı Ana Bilim Dalı
Danışman: Doç. Dr. Onur ŞATIR
Eylül 2018, 119 sayfa

Kentsel gelişme, insan refahı ve kentlerin sürdürülebilirliği açısından risk oluşturan çevresel ve sosyal endişelere neden olmaktadır. Sorunları, sürdürülebilir ve doğal bir şekilde azaltmak için yeni yeşil mimari kavramları geliştirilmektedir. Çatı ve dikey yeşillendirme sistemleri, bitki örtüsünün bir bina veya cephe veya iç duvar üzerine yayılmasına izin veren yapılar olarak tanımlanabilir. Bu sistemler yavaş yavaş evrimleşmeye başlamış ve bazı özel etkilere sahiptirler. Son beş yılda, bu konudaki bilimsel literatürde yayımlanan, özellikle canlı çatı ve yaşayan duvarları içeren çalışmaların sayısı önemli ölçüde artmıştır. Bu bilimsel ilgi, halkın artan ve paralel olarak dikkat çektiği bir konuya işarettir. Bu çalışma, farklı sistemlerin geniş bir tanımını ve bu yeşil altyapıların özel faydalarını kapsamlı bir şekilde incelemek amacıyla yapılmaktadır. Ayrıca, bu çalışmada, Erbil kentinin özel olarak seçilen bazı bölgelerine canlı çatı ve dikey bahçelerle örnek bir simülasyon tasarlanmıştır.



**Anahtar kelimeler**: Biyomimikri, Enerji tasarrufu, Kentsel ekoloji, Kent yeşilliği, Sürdürülebilir inşaat, Yapılı çevre, Yaşayan duvarlar, Yeşil çatı.

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July 2018

Darbaz Pirot MANKURI

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## SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below, along with descriptions.

| Abbreviations | Description |
|---|---|
| **UHI** | Urban heat island |
| **EPA** | United States Environmental Protection Agency |
| **Csa** | Hot-summer mediterranean climate |
| **IKR** | Iraqi kurdistan region |

# 1. INTRODUCTION

## 1.1. Background

Similar to several other cities, Erbil faces continual stress from growing urbanization (Yahya et al., 2015). Quick resident increasing and urban improvement have been converted native habitats into places of huge engineered structure. Heat production from cars, factories and business areas, fixed with the holding of the solar energy by constructions and covered faces. Producing oddly warm urban environments are recognized as urban heat islands. Urban heat island is one of the most famous issues of anthropogenic impact of global warming. Urban areas have artificial characteristics due to built-up materials such as concrete, asphalt and metal structures (Ngiea et al., 2014). The constructed material can be warmer than water and vegetable surfaces. In addition, high "C" and $CH_4$ gases retain warm air around the city's atmosphere. So, the air temperature and LST of the built-up areas are usually larger than around. This can be caused bad impacts on human healthiness. The conversion from the natural landscape to the constructed environments are affected vegetation and habitants in negative way. All of these problems are aggravated pressure on urban environment particular climate (Rogers, 2008). Green vegetation plays an important role in urban areas (Gairola and Noresah, 2010). Some of the many advantages of urban green areas: air and water purification, environmental pollution mitigation, carbon capture, microclimate regulation, habitat for urban wildlife, recreational, spiritual and therapeutic value, and social integration (Gairola and Noresah, 2010). Plan makers are needed to think new methods to make our cites more suitable for living because of current ecological problems. Several cities in the world are recognized the significance of having green substructure such as natural landscape resources involving water systems and green spaces. Green substructure involves plants, gardens, roof gardens, facades, wall gardens and water sensitive urban design (wetlands and rain gardens) (Rogers, 2008).

Roof gardens, facades, and wall gardens are attractive designing techniques to increasing green substructure in a city that can be involved on new buildings or renewed on to current buildings. They are being used to recompense for the damage of urban green area, and to supply localization to become less hot and beauty perfections in thick urban centers where there is deficient space for other kinds of green substructure. (Rogers, 2008)

Unfortunately, there is no vertical and roof garden in Erbil right now. The percentage of green in Erbil city that is capital of IKR is less than 7% that is a dangerous single because the international rate must be %30 (Yahya et al., 2015). Yet, there is restricted evidence in IKR about how to make and accomplish these kinds of green substructure. This guide offers practical guidance on how to design, create and accomplish roof garden, facades and walls garden so they can offer various profits over a long-time extent for building landlords and the wider public (Yahya et al., 2015).

## 1.2. Research Problem

The predominance of building on open spaces and the lack of green spaces, and the problems of the architect in creating an entrance that contributes to the creation of green areas in areas with high population density. It can be summarized as the erosion of green areas, which has become parallel to increasing the density of the favorable environment, which negatively affects the environment by changing the general characteristics of the local climate. Reference backgrounds for increasing green areas and overcoming problems of either design, environmental or other related to the scarcity of land space that can be converted to green areas (Figure 1.1). Creating an entrance that contributes to the creation of additional green areas in urban areas (Figure 1.2; Rogers, 2008).

Understand the structural systems of vertical preparation systems. Contribute to the absorption of green areas over the roofs of buildings by green surfaces experimenting the production surfaces and their compatibility with the foundations and controls of the design of the green surfaces and the possibility of developing them for integrated surface gardens (Rogers, 2008).

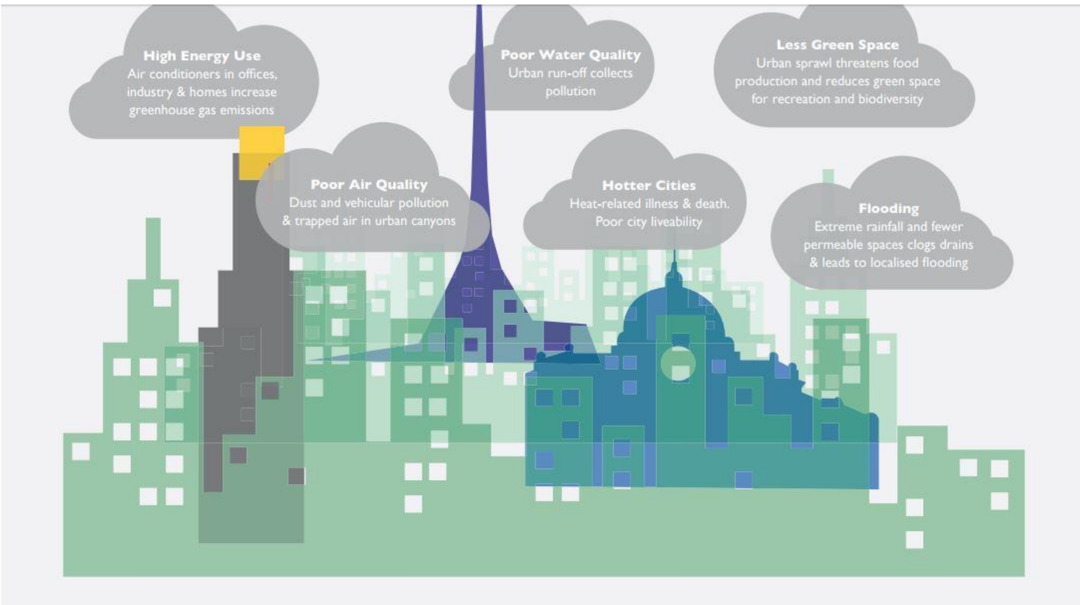


Figure 1.1. Pressure builds over our cities, with the changeover from natural landscapes to solid substructure, a gradually variable climate and an increasing population (Carpenter, 2014).

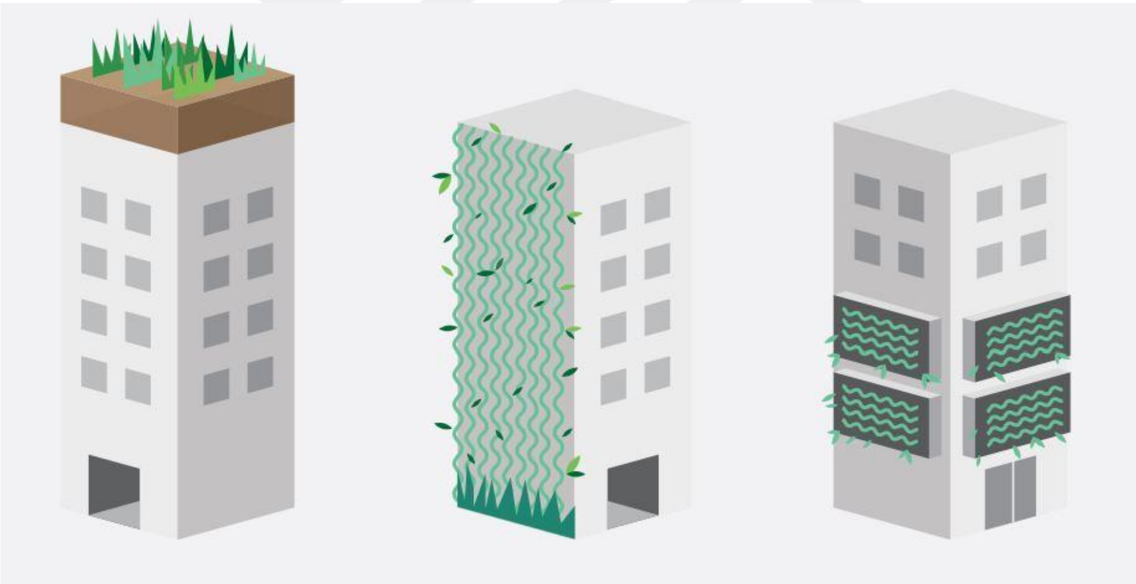

Figure 1.2. Vegetation can be added to a building like green roof, green façade or green wall (Carpenter, 2014).

## 1.3. Importance of the Study

This dilemma has placed the importance of trying deeper research into: The concept and application of vertical planning systems, and the application of the thought of coordination of sites in the vertical direction in order to achieve the maximum satisfaction of the material and non-physical needs of the users of the building and find a means of communication with the environment surrounding.

The surface garden is no less environmentally important than the green areas in general, including green plant elements that contribute to the supply of oxygen, Carbon dioxide absorption and air purification in general. It also reduces overall pollution impacts, absorbs noise, reduces optical luminance and provides shade, and also exudes atmosphere. Surface gardens feature ground gardens in being far from noise and acoustic pollution and illustrate the two (Figure 1.3, 1.4) The difference between the roofs of our homes in Erbil and the European countries, in addition, it acts as a thermal insulator for the final surface, in addition to the types of plants that absorb wind speed and intensity and turn it into a nice breeze.

Figure 1.3. Image showing the state of the surfaces in Erbil (Anonymous, 2017a).

Figure 1.4. Picture showing the green roofs of London (Rogers, 2008).

The Green wall and the Green roof are developing technologies that have been used in different countries to improve the thermal characteristics of buildings through their use on walls and roofs respectively These systems consist of suitable plants for a particular climate, planted or filled in soil with several layers, and then fixed in a structure, living walls are sometimes called Vertical vegetation or Green walls. The Living Wall system can be grown straight on the facade of the building, or it can be grown on a separate structural system that adjoins the wall and sometimes attaches to it. Living walls are designed, built and preserved elements of vegetation associated with the building. Green facade systems can be installed by wire or a pot system in front of a building's walls or windows. Green roof systems are being implemented in many buildings around the world to provide higher thermal performance and roof insulation. A green roof is a surface partially or completely covered with vegetation and a growing medium above the waterproofing membrane. The green roof acts as an insulating barrier and reduces the amount of solar energy absorbed by the roof membrane, which results in colder temperatures below the surface.

Green roofs refer to thousands of years. History reveals the diversity of the goals of these roofs, which include insulating qualities, and avoid the stress of the urban environment. The oldest green roof, apparently, is a ziggurat of ancient Mesopotamia, built from the fourth millennium to 600 BC. located in the courtyards of churches in major cities (Groninger et al., 2011). It was recorded that the green roofs were used on the Hanging Garden of Babylon and in the houses of the Scandinavian Vikings (Anonymous, 2015b).

Grass roofs have been a feature of the vernacular architecture of certain geographic regions notably Scandinavia and The Fertile Crescent, areas of Turkey, Iraq, Iran, and neighboring countries occupied by Kurdish-speaking peoples (Dunnett and Kingsbury, 2008) for centuries, probably millennia. Mud or earth is a traditional building material in this region. Flat, mud-covered roofs often become colonized with grasses, producing the turf-roof effect. Local name of these houses called kurdish turf roof. The combined soil and grass on Scandinavian roofs helped reduce heat loss during the long, dark winters (Dunnett and Kingsbury, 2008). Traditional Kurdish turf roofs serve to keep in heat during the winter and keep out the burning sun in summer months. Scandinavian immigrants to the United States and Canada brought these ideas with them, and for some time, grass roofs were used on settler log cabins (House, 2009).

In modern times there were two proponents of the application of the "green roof" architects Le Corbusier and Frank Lloyd Wright. Although Le Corbusier encouraged the roofs as another place for urban green space, and Wright used green roofs as a tool for closer integration of his buildings with the landscape and was unaware of the deep environmental and economic consequences this technology could have for the urban landscape (Yeang, 1999). In the 1970s, a significant amount of technical research on various components of the green roof technology was carried out, including research on substances, repelling roots, waterproof membranes, drainage, light plant media and plants (Anonymous, 2015b). Currently, green roofs are becoming more common in the United States, although other countries are farther in adopting green roof systems (Yeang, 1999).

In the early 1990s, several large European green roof manufacturers began to enter the markets of North America. And in 1931 in New York the Rockefeller Center was built as the first modern green roof known to us (Anonymous, 2015b). But before that, Canada and the United States lagged behind Europe for at least a decade in investing in the green roof infrastructure as a viable option for addressing many of the quality of life problems facing our cities (Anonymous, 2015b). Green roofs have long been associated with sustainability, as it is usually the best replacement for the loss of the green zone in the construction of the building. This is also one of the typical methods used in the principles of sustainable development (Zahira et al., 2013). Green roofs are now a new trend of aesthetic, ecological, economic and, above all, sustainable solutions to urban environmental problems (Yahya et al., 2015).

Green roofs can extend the life of the roof by two or three times. According to the Sustainable South Bronx, on day 90 degrees the green roof is about 80 ° F and the black roof is 175 ° F, causing considerable wear (Sailor, 2010). A study at the University of Central Florida showed that the maximum average daily temperature for a typical roof surface was 130 ° F, and the maximum average for a green roof was 91 ° F, which is 39 ° F lower than a conventional roof (Sailor, 2010). Green roofs can help regulate the internal temperature of the building, reduce rainfall and mitigate the effect of the city's thermal island. Green roofs have significant economic benefits, including longer roof life and energy savings for heating and cooling. Green roofs also provide an opportunity to produce food in cities and increase the biodiversity of cities. If well designed and cared for, green roofs can offer people the psychological benefits of nature (Anonymous, 2010c).

The advantages of using a living wall, a green facade and a green roof are many. The temperatures behind the green walls can be reduced by as much as 10 degrees celsius. Green walls can help reduce sound reflection. Due to shading green walls can reduce summer temperatures and reduce energy costs by 23 percent (Loh, 2008). Numerous researchers, scientists and scientists have described the benefits of using these applications for green color (Sclar, 2013). Using these Green applications, you can get economic, environmental and social benefits (Loh, 2008). The use of residential walls, a green facade and a green roof during the design and operation phase of the building can reduce wall and roof heat, energy consumption, greenhouse gas emissions, the effect of the city's thermal island, electricity costs and noise pollution. These approaches improve the thermal and energy characteristics of buildings in a particular climate, as well as indoor air quality and encourage the use of green and clean energy (Hasan, 2013).

### 1.4. The Objective of Study

The main objectives of the study are determining constrains and challenges of green roofs application in Erbil city as case field by analyzing international experiences and concluding Erbil green roofs criteria. evaluating the appropriate applications of the green roofs and vertical gardens in the world. Designing a sample application of a green roof and vertical garden to a part of Erbil area. An entrance that contributes to the absorption of green areas within the urban boundaries of areas with high population density by exploiting roofs of residential buildings. The economic factor in the contribution of the green element in reducing the needs of the material population. Improving the natural environment through the process of biological filtration that are working on green areas by reducing the pollutants in the air. The social aspect of providing free space for recreational activities and a safe place for children to play. Reduced green spaces on the urban level by increasing the percentage of individual green areas.

# 2. LITRATURE REVIEW

## 2.1 Introduction

This chapter provides an overview of research and literature on numerous types of green roofs and walls, as well as their history, as well as the environmental influence that green roofs and walls have in buildings, as well as the chances they bring to reduce the effect of the urban heat island and the microclimate in the center of Erbil. This chapter also discusses why simulations are significant and related in design literature. In addition, an overview of other studies conducted in different cities was reviewed to understand the influence and the process of informing on where to place new green walls and roofs. The survey provides a basis for understanding where and why it is significant to add green roofs and walls in the center of Erbil.

## 2.2 Green Roofs and Green Walls

### 2.2.1 Green roofs

Planting vegetation on the roofs of buildings occurs from the hanging gardens of Babylon (Henry and Frascaria-Lacoste, 2012). They were used as horticultural and architectural elements, but recently this practice is gaining more strength to protect the tops of buildings from the effects of solar radiation, precipitation and wind. Green roofs are believed that improve energy efficiency, influence the impact of storm water, attract wildlife in urban areas (Henry and Frascaria-Lacoste, 2012). and provide access to nature and pleasure in one of the least probable parts of buildings. A green roof can be a flat or inclined roof surface designed to support the vegetation of conversations working as a fully functioning roof (Goddard et al., 2009). Green roofs have various layers which are waterproofing, root barrier, drainage and filter membranes; the substrate layer is designed to provide vegetation growth (Dvorak and Volder, 2010).

Green roofs backing plant communities that are tolerant of extreme weather conditions facing on rooftops. The thicker the substrate layer, the more diverse the vegetation (Henry and Frascaria-Lacoste, 2012). There are two different types of green roofs: intensive ones that have a thicker substrate layer and extensive ones with a thin layer of substrate (Table 2.1).

Intensive living roofs are accessible installations with a thicker substrate layer that allow a variety of plant variants from ground coatings to trees. Typically, these types of systems allow space to function as a useful area and are mostly used in commercial buildings. For intensive systems, significant maintenance may be required, and their cost is also higher (House, 2009) (Figure 2.1).

Figure 2.1. Intensive green roof (Anonymous, 2010d).

Extensive living roofs are often inaccessible to install with thinner substrate layers. Because of the thin layer, plant and size of the species is limited. An extensive living roof is more prevalent because of the low maintenance cost and because it can be added to an existing building without more preparation. There are two types of extensive green roofs: modular and monolithic.

Monolithic systems overlay the roof area (Figure 2.2), while modular systems use vessels (Figure 2.3) (Anonymous, 2012f).

Figure 2.2. Extensive living roof monolithic System (Sclar, 2013).

Figure 2.3. Extensive living roof modular system (Sclar, 2013).

Table 2.1. Green roofs definition of typologies

| Terminology | Definition |
|---|---|
| Green roof | Planted living roof (Oberndorfer, 2007; Henry and Frascaria-Lacoste, 2012). |
| Living roof | Any vegetated roof system either 'brown' or 'green' (Oberndorfer, 2007; Henry and Frascaria-Lacoste, 2012). |
| Intensive living/green roof | A 'roof garden' where the purpose is mainly recreational or aesthetic like a regular garden. This type of roofs will have deeper soil, require regular maintenance and can support a wide variety of plants (Oberndorfer, Henry and Frascaria-Lacoste, 2012). |
| Extensive living/green roof | A roof generated to support biodiversity or other environmental benefits and is not intended to be used by humans. Usually it contains a thinner soil layer and after construction it requires minimal maintenance (Oberndorfer, 2007; Henry and Frascaria-Lacoste, 2012). |

When a building is built the flow of energy and matter through urban ecosystems changes, which usually causes environmental problems (Oberndorfer et al., 2007). By changing the surface properties of buildings, you can reduce environmental problems that they can cause. Roofs can be up to 32% horizontal surface in built-up areas (Frazer, 2005) and are important factors determining the flow of energy and water relationships of buildings. The negative impact on buildings can be reduced When vegetation and soil are added to the roof surfaces, by reducing the energy consumption of buildings. It has been shown that living or green roofs increase sound insulation (Dunnett and Kingsbury, 2004), fire resistance (Köhler, 2003) and the resistance of the roof membrane (Porsche and Köhler, 2003).

They can reduce the energy needed to maintain the internal climate (Del Barrio, 1998), as vegetation and growing plant environments capture and dissipate solar radiation.

Green roofs can also soften storm water from building surfaces by collecting and retaining sediments, thereby reducing the amount of water flow into the storm water infrastructure and urban waterways" (Oberndorfer et al., 2007). Other advantages of green roofs are that they can become green amenities, a wildlife habitat, improve air quality and reduce the impact of a city's thermal island (Getter and Rowe, 2006). Despite the fact that green roofs are at first more expensive than conventional roofs, long-term advantages are worth it due to energy savings and the durability of roofing membranes (Porsche and Köhler, 2003). The environmental benefits provided by green roofs stem from their functioning as an ecosystem "(Oberndorfer et al., 2007). It is significant to consider that climatic conditions on the roof of buildings can be risky due to precipitation, temperature and strong winds. Due to the before mentioned conditions, pasture plants can be limited. using of native plants is generally considered to be the ideal choice for roof landscapes, since their adaptation to local climates and natural stress-tolerant flora (in particular, dry pastures, coastal and alpine floras) in many regions offer opportunities for trial and experience (Oberndorfer et al., 2007). The advantages of green roofs are reduced to three main categories: energy saving; storm water management; and the provision of habitats in habitats.

Urban areas have more impenetrable surfaces than permeable surfaces, which makes storm water management more difficult; because of this, green roofs can become a good storm water management infrastructure. Furthermore, to exacerbating floods, erosion and sedimentation, urban runoff also has a high level of pollution, such as insecticides and oil remains that damage habitats of wild animals and contaminate drinking water supplies (Moran et al., 2005). Other types of storm water have built wetlands, ponds, sand filters and rain gardens; unfortunately, they are difficult to do in dense urban areas. The green roof has the greatest impact on energy using for buildings with high roof-to-wall ratios (Oberndorfer et al., 2007).

### 2.2.2 Green walls

Green facades or green walls have historically been used as a decorative or horticultural element. History archived that the first documented green structures were the hanging gardens of Babylon in Mesopotamia (Henry and Frascaria-Lacoste, 2012).

Green walls are the outcome of the planting of vertical surfaces with plants, whether plants that are rooted in the ground, in the wall itself or in modular panels that are linked to the facade. Green walls are vegetated vertical surfaces, which are divided into two types (Table 2.2).

1) Green facades are façade systems in which climbing plants are rooted in soil or containers, either grow upward or cascade down and they require a structure to maintain their position, growth and overall survival. With green facades, you can use a wide range of plant species, and this system is easily scaled (Anonymous, 2015e). Then the green facades can be divided into three systems: traditional green facades, in which climbing plants use façade material as a support (Figure 2.4), and by doing this, climbers land in the ground at the bottom of the building, this being the cheapest of all green facade systems. Using this system could harm the facade, and plants planted in this way can grow to a height of eighty feet and can take several years (Ottele et al., 2011). A double leather green facade or green curtain is when the facade is separated from the wall (Figure 2.1). And, finally, the flower vessels around the perimeter, when part of the building of the facade, hanging bushes, is planted around the building, making a green curtain (Perez et al., 2011) (Figure 2.2).

Figure 2.4. Example of traditional green façade, Miami, Florida (Bielaz, 2013).

Figure 2.5. Double skin green facade (Sclar, 2013).


Figure 2.6. Perimeter flowerpots (Sclar, 2013).

2) Living walls are a new technological system that depends on a modular or monolithic vertical soil or a hydroponic system with root plants on a vertical plane (Anonymous, 2015e). They are made of panels and / or geotextile felt. on occasion they

are pre-cultivated and constant on a vertical support on the wall. Geotextiles worked by supporting various plant materials (Perez et al., 2011). A living wall can be considered as a vertical garden, which means that a regular garden, such as irrigation, drainage and how to arrange everything vertically (Figure 2.4). Since this is a new technology, it has been difficult to make plants survive for a long period of time and on a large surface. In addition, the production of a living wall system is more expensive, as is the green facade during installation, replacement of plants and maintenance (Anonymous, 2015e).

Figure 2.7. Living wall in Mexico City (Bielaz, 2013).

Green vertical systems can also be divided into two building systems: extensive and intensive. Extensive systems are easy to construction and require minimal future maintenance after construction; more intensive systems are more completed and require a high level of service after construction.

Green vertical systems can be used as passive energy-saving systems with the assistance of four techniques: objection of solar radiation due to shade created by vegetation, insulation produced by vegetation when linked to the building wall, wind blocking and the evaporative cooling effect that occurs during evapotranspiration of plants (Perez et al., 2011). Starting with solar radiation as a result of the shadow made by vegetation, it is noted that the area wrapped by shade trees can save up to %30 of the cooling energy. Experimenting with traditional green facades, (Bielaz, 2013) found that the size of this shadow impact depends on the density of the foliage. Lvies are species that equipping the maximum cooling effect similar to a shade of trees. Differences to 3 celsius were noticed at room temperature in winter (Köhler, 2008, Perez et al., 2011). This procedure works by filtering direct sunlight on the facade with leaves. Because of the effect of phototropism, when one hundred percent of light falls into leaves, five to thirty percent of this light is reflected, five to twenty percent of this light is used for photosynthesis, from ten to fifty percent is converted into heat, twenty to forty percent is used for evapotranspiration and through thirty percent passes through the leaves (Ottele et al., 2011). New studies researches have shown that climbing plants also have a cooling effect on the surface of the building, even in hot seasons, which is very worthy in a warm climate specially in summer (Perez et al., 2011; Ottele et al., 2011).

Secondly, the insulation made by vegetation between the walls the of the building and green screen makes changes in environmental conditions such as humidity and temperature. The space between the green facade and the building creates a stagnant air layer that makes an insulation influence (Ottele et al., 2011). The insulating capacity of living walls can depend on the thickness of the substrate. When the concrete wall that is not covered with vegetation, the heat transfer is upper than the concrete wall is covered with vegetation; a living wall can decrease the energy that is transferred to the building at 0.24 kWh / m2 (Hoyano, 1988). "In researches on traditional façades, a development in heat loss of up to %25 on the northern facade was measured though this development depended on the insulation levels of the building" (Köhler, 2008, Perez et al., 2011).

Thirdly, the green wall system works as a wind barrier and, as a result, blocks the impact of winds on the facades of the building. The impact depends on a number of characteristics: the permeability of vegetation and density, the orientation of the wall, and the direction and speed of the wind. All these measurements assist to improve the energy efficiency of the building by blocking the wind alone, decreasing the need for air conditioning in the summer and heating in winter (Dinsdale et al., Perez et al., 2011). while using green facades as a component for blocking wind, it is significant not to prevent ventilation in the summer and not help in the circulation of cold air in winter. The wind reduces the energy efficiency of the building by %50 according to (Ottele et al., 2011), but, using a vegetative layer, the green facade works as a buffer and prevents the movement of wind along the surface of the building.

Table 2.2. Green walls definition of typologies

| Terminology | Definition |
|---|---|
| Green façade | It refers to climbing plants that are encouraged to grow and along the walls of buildings with the formation of a green cover, the roots of the plants are contained in the base of the wall. Sometimes these plants should grow on a wire or lattice basis (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |
| Living wall | A wall that includes vegetation by its structure or surface, which does not require that the plants are rooted at the base of the wall, as in a green facade. Most residential walls are modular systems and consist of a coated environment that is placed on the wall surface but separated from the wall material by a waterproof membrane and watered using a droplet delivery system. Sometimes they can be subjected to bioengineering, so that plant roots are used as an amplifying mechanism inside the wall system (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |
| Biowall | Living wall or green facade, which is placed indoors. It is used to improve the atmosphere and the internal environment (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |

The last of the negative mechanisms of energy saving through green walls is the effect of evaporative cooling during evapotranspiration, which demand energy. This effect of evaporative cooling depends on the type of plants and their effect. It was studied that when the area is covered with trees, the cooling impact due to plant evapotranspiration results in a reduce in temperature around the buildings. The green facades cool the air with evapotranspiration, and as a consequence, with every decrease in the internal air temperature of the building at 5 C, the use of electricity in the building for an air conditioning system can be reduced by 8% in the summer. In winter, the thermal radiation from the outer walls is isolated by vegetation (Ottele et al., 2011).

According to (Wong, 2008), since the isolation applied to the exterior of buildings is much more effective than internal insulation, essentially in the summer months, vertical green systems will have a twofold effect of reducing incoming solar energy to the interior by shading and decreasing heat flow into the building through evaporative cooling, increasing energy savings. (Perez et al., 2011)

### 2.2.3 Recent research on green walls and green roofs

The use of green walls and roofs is not a new concept, as it is widely covered in recent literature. Green walls and green roofs represent economic, social and environmental benefits. Green roofs and greening facades are a combination of nature and buildings that can help solve ecological problems, especially in dense urban areas. (Bielaz, 2013) They help to increase biodiversity and environmental value, mitigate the impact of the city's thermal island, decrease the temperature of the building inside and outside, provide insulation, improve air quality and social and psychological well-being of citizens (Ottele et al., 2011). The following table illustrates some of the most recent published research on the topic with their emphasis areas.

## 2.3 Experience of the Green Roofs Internationally and Locally

Through this part of the study, the experiences in other countries in the field of green roofs adopted by policies and governments are being followed to pave the way for the green roofs, not only in housing projects in Abril, but also in all uses as an approach to energy saving, reducing the thermal island phenomenon and taking advantage of the environmental aspects. Local experience is also monitored from individual experiences to what is now known as "productive gardens on the roofs of Iraqi dwellings".

### 2.3.1. Experience of green roofs in Europe

#### 2.3.1.1. Germany

Germany has a leading position in green roof technology worldwide. They are the leading manufacturers of green roof systems. In the beginning of the year 1980 in the

Table 2.3. Green roofs and green walls literature review matrix

| Author (s) | Article Title | Date of Publication | Category or Emphasis |
|---|---|---|---|
| Francis and Lorimer | Urban Reconciliation ecology: The potential of living roofs and walls | 2011 | Biodiversity potential of living roofs and walls |
| Oberndorfer et al | Green Roofs as Urban Ecosystems: Ecological Structures, Functions and Services | 2007 | Potential of green roofs to act as ecosystems |
| Perez et al. | Green vertical systems for buildings as a passive system for energy savings | 2011 | Ecological and environmental benefits of green walls |
| Alexandri and Jones | Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates | 2006 | |
| Perini et al. | Vertical greening systems and the effect on air flow and temperature on the building envelope | 2011 | The impact of green walls and roofs in the thermal performance of the building and the effect in the urban environment |
| Green Screen | Considerations for Advanced Green Façade Design | 2012 | Living Architecture |
| Mazzali et al. | Experimental investigation on the energy performance of Living Walls in a temperate climate | 2013 | Living walls serve as a cooling energy reduction |
| Santamouris | Cooling the cities. A review of reflective and green roof mitigation technologies to reduce heat island and improve comfort in urban environments | 2012 | Mitigation potential of green roofs |
| Blanc | The Vertical Garden A scientific and Artistic approach | 2008 | Green walls as a second skin of buildings |
| Susorova et al. | A model of vegetated exterior façades for evaluation of wall thermal performance | 2013 | Reduction of temperature inside and outside of building when green façade is placed |
| Yahya et al | Green Roofs and Their Implementation in Architecture The obstacle and challenges in Erbil city | 2015 | Green Roof and Environmental Problems |

city of Stuttgart it has been providing official government support for the first project implemented by green surfaces. Another catalyst published in 1982, the first standards set green roofs by (Association for Development and Research Building landscape elements: FLL) these standards have been updated over successive years to reflect lessons learned from several projects. In 1998, a new code was introduced under the German Building Code "Federal Building Code of Germany" to meet the requirements and foundations for the greening of the green surfaces in Germany.

Part of the reason for this development at this early time was the Federal Nature Protection Act, which influenced the construction codes, new development projects required by replacing and strengthening the elements of the landscape in line with this amendment in the building code. (Dunnett and Kingsbury, 2008) Today, at least 48 German cities support the establishment of green roofs, which is equivalent to 35% of the German cities. It has implemented the policy of applying green roofs in different buildings, various uses and functional purposes. Now the total number of green surfaces in Germany is 86 million square meters, equivalent to 14% of the total area of Germany (Baykal, 2012).

**2.3.1.2. European countries**

London Mayor Johnson Boris has implemented a plan to set up a minimum of 100,000 square meters of green roofs by 2012. Similar legislation exists in other Nordic countries such as Switzerland, Sweden, Norway and Austria. In Switzerland, 25% of new urban communities are required to integrate green surfaces, if a certain percentage of the green roofs are achieved in the new projects, the project owners will have the right to increase the building area (Baykal, 2012).

There are also grants from the government and local city bodies, as well as numerous organizations that provide support and guidance to those who wish to include the issue of green roofs in new and existing buildings (Eid, 2014).

Figure 2.8. Green roofs in Stuttgart, Germany (Costanzo, 2016).

Figure 2.9. Part of the university (Cantonal) hospital in Basel, Switzerland (Anonymous, 2013i).

### 2.3.2. Experience of green roofs in Asian countries

In the far east, especially Singapore and Japan, attention to the impact of green roofs on the heat of the urban island has encouraged research and change. All new projects with an area of more than 1,000 square meters should be renewed at least 20% of the site in cultivated areas, which encourages the use of green roofs (Eid, 2014).

#### 2.3.2.1. Singapore

The Government has implemented a scheme called Scheme Incentive Greenery Skyrise (SGIS) and has drawn up a plan for implementation between 2009 and 2015. The scheme supports 50% of the costs of installation from the roofs of green buildings and green walls. Singapore has emphasized that such urban development is to ensure maximum soil use and to accommodate a steady population increase through vertical urbanization. In 2005, Singapore launched the Certification Mark Green BCA, an initiative to manage the construction and construction industry in Singapore towards more environmentally friendly buildings (Eid, 2014).

Figure 2.10. Singapore, school campus NTU (Eid, 2014).

#### 2.3.2.2. China, Beijing

Since 2003, a campaign has been launched to promote green building surfaces for all concerned parties, in 2008, the city's total green roofs reached 500,000 square feet, equivalent to 7% of the city. The city of Beijing has various policies and programs that enhance the roofs of green buildings. In 2008, the total green area was 1,000,000 square meters and since then, 100,000 square meters of green roofs have been built annually (Mclntosh, 2010).

Figure 2.11. Green roof in Beijing city

Figure 2.12. Green roof in Xiamen city. (Anonymous, 2010j).

### 2.3.3. Experience of green roofs in north America and Canada

The green roofs of North America and Canada are not as advanced as those of European countries, and their increased awareness of growth began in the previous few years through research projects that led to the realization of the importance of saving energy and money in the heating and cooling of buildings. Green surfaces are seen as an effective way of reducing "heat island effect". The first financial grant was launched in Canada to induce green roofs in buildings by s'Quebec Energy Board: The Green-Roof Financial Incentive Program (Philippe, 2008). However, there are purposes other basic reinforced the importance of green surfaces in those countries. In Portland, there are important about dealing with storm water as the entry of contaminated water into rivers, causing damage to the local salmon (Mclntosh, 2010).

#### 2.3.3.1. United States of America, Chicago

Today, green surfaces are part of the state's sustainability plan. Through the State Department of Planning and Development, the "density incentive" program is implemented by the government and investors through government grants to investors who design a building with vegetation covering 50% of the total surface of the building or 186 square meters (whichever is larger), usually in the form of a "roof garden (Eid, 2014).

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Figure 2.13. Chicago City hall green roof (Eid, 2014).

**2.3.3.2. Toronto, Canada**

Regulatory requirements in Toronto in 2009 called for a green roof policy on new commercial, institutional and residential buildings with a minimum total area of 2,000 square meters to be made from 31 January 2010. Since April 30, 2012, the roofs of green buildings have been applied to new industrial buildings by:

Create a green surface that covers a minimum of 10% of the building's surface area or 2000 square meters (Eid, 2014).

Figure 2.14. A green roof in Toronto city Canada (Eid, 2014).

**2.3.4. Australia: Melbourne and Sydney**

There are no requirements or conditions in the two cities for the foundations and regulations for the construction of green surfaces. However, the city of Sydney has issued a reference manual for the construction of the green roofs, and through the response of users, the city has more than 60 surface and green walls for multi-use buildings (Carpenter, 2011).

Figure 2.15. A green roof in Australia (Anonymous, 2016q).

### 2.3.5 Experiments on green surfaces in Arab countries

In Beirut: Due to overcrowding in the buildings turned into a cement forest, and the space available for the establishment of green parks was greatly reduced it became impossible to cultivate roadsides and sidewalks, thus, the idea of surface cultivation is appropriate for the Lebanese capital. Currently there are about 18,500 buildings with vacant roofs. By planting only one tree per building, the output will be 18,500 trees, equal to the number of trees in Central Park in New York. The project goes beyond the planting of a single tree. The project of the gardens or the forest of Beirut goes on two tracks: first, the feasibility of implementing the proposal by placing trees on some surfaces as experimental models, As well as the presentation of the project to the Municipality of Beirut, ministries of environment and agriculture, data collection and research. The second track is lobbying for a new law at the municipal level to support the project (Eid, 2014).

Figure 2.16. An imaginary form of a hanging garden project in Beirut, trees on every building turning Beirut into a reen forest (Eid, 2014).

### 2.3.6 Experience of green surfaces in Islamic countries, Iran

Following the arrival of a new wave of global awareness about environmental problems, many environmentalists and elites have become aware of this environmental crisis and its impact on urban areas. More recently, the search for vertical preparation systems has increased in universities, environmental non-governmental organizations and architectural journals (Eid, 2014).

Figure 2.17. Giant green roof in Tehran Iran (Eid, 2014).

### 2.3.7 Experience of green roofs in northern of Iraq

Interestingly, recent statistics show that the share of green zones in Erbil in the capital of IKR is about 6.5%, whereas in accordance with international standards, 30% of urban areas should be green. Moreover, in Kurdish people do not have enough awareness that planting trees is favorable for the atmosphere and can lead to better living conditions for them and their children. Strangely enough, not only some people do not plant trees, they sometimes uproot or cut trees planted by the government. Without a national campaign by the people and the government to increase green zones and encourage nature in the future, little hope is expected (Yahya et al., 2015).

## 2.4. Green Roof and Vertical Garden Examples

### 2.4.1. The Jean Vollum Natural Capital Center

It is a condominium for a group of tenants and is not aimed at its owner to earn and profit from the lung, and the building is specifically located in 21 NW 9th Avenue, Portland, Oregon. It is a historic building in the Portland city center, where it was opened in 2001 after renovation and renovation, and the addition of a third floor, as follows, shows the entire building (Lena et al., 2009).

Figure 2.18. The Jean vollum natural capital Center (Lena et al., 2009).

The renovation included the installation or construction of a green roof, and the reason for its construction to provide renters, a preferred space for recreation and meeting (Lena et al., 2009).

The scene on the ceiling shows a large-scale 2000-square-meter green roof; the cost of its construction is estimated at $ 75,000 more than the standard ceiling and can be accessed by residents of the building and for maintenance only. This green ceiling is designed using a lightweight system that includes a 10 cm membrane of soil (medium growth) Copper is a root barrier, a drainage layer for surplus water, and the use of flowers is a regional herb. The sinter layer is white polyester, which carries packs of hydrogen peroxide that swell to store water when the rain falls. As these crystals swell with water and form peaks. The excess water is channeled into narrow valleys between the peaks, which serve as outlets for drainage. The project includes several sustainable design features, including rainwater filtering through the green roof. In addition, more than 80% of the surface drainage of the site is used to irrigate the green areas. The project also used recycled construction waste, and also installed and used clean energy (solar cells) as shown below and designed the project to achieve maximum natural light and observations of occupants of the building. The project received a USGBC Golden rating of LEED (Lena et al., 2009).

Figure 2.19. Shows the use of local flowers Figure 2.20. The building uses solar cells with a green roof (Lena et al., 2009).

From the above, we find that the green ceiling that was built here on an old historic building in the city is a large-scale green roof type, which is of a simple type and does not add high loads and weights to the building and therefore this type as described in this building can be applied locally in Iraq in the existing buildings and these are the positive received from this building And the success rate may be high, especially in residential buildings that were not designed to calculate the additional loads and because this type is simple and easy to build and load is simple, it will be very successful in the new and old housing buildings in Iraqi cities; It also provides psychological comfort and provides a place for recreation and gives aesthetics to the building; and also this project encourages research to determine the feasibility of applying such techniques in Iraq.

The disadvantages of this project are the use of local plants that bear the local climate of the city in question, the United States of America (Oregon State in Portland). Therefore, if applied in Iraq, it is necessary to find plants that adapt to the local climate of Iraq (Mohamed and Abdul, 2015).

### 2.4.2. The Fairmont Waterfront Hotel Herb Garden

It is a hotel and restaurant in downtown Vancouver, specifically 900 Canada Place Way, Vancouver, British Columbia; the figure below shows the entire building. The green roof is built at the top of the restaurant roof. It is a 200m² thick green roof. This roof provides the restaurant with an annual budget of $ 20,000- $ 20.25. This includes the plants used in the restaurant, as shown in the figure below. Non-purchase of plant crops from local markets is available in the green ceiling. (Lena et al, 2009).

The green ceiling is accessible as a green open space used by hotel guests and guests, is carefully cared for and maintained in the style of any yard or patio. The annual maintenance cost of the green roof is estimated at approximately $ 16,000. This roof consists of concrete slab with a homogeneous membrane of two layers of waterproofing material and 30 cm of insulating foam and a piece of cloth for drainage in addition to rocks and soil where the ceiling is designed to accommodate the soil weight and plants (Lena et al. 2009). The benefits obtained from this hotel due to the establishment of the green roof as well as the provision of plant crops for the restaurant and use as a place of rest and recreation, the rooms overlooking this green ceiling is of a special nature has been given the importance of more distinctive and more detailed decoration and opened private balconies, Above the other rooms as shown in the figure below (Lena et al., 2009).

Figure 2.21. The fairmont Waterfront Hotel herb garden (Lena et al., 2009).

Figure 2.22. Use of plant crops in the roof of the green hotel (Lena et al., 2009).

Green roof is used. This type requires preloading during the design process. This type may also be applied in Iraq if the weights of this type are preset. The project also encourages research to determine the applicability of such techniques in Iraq. (Mohamed and Abdul, 2015).

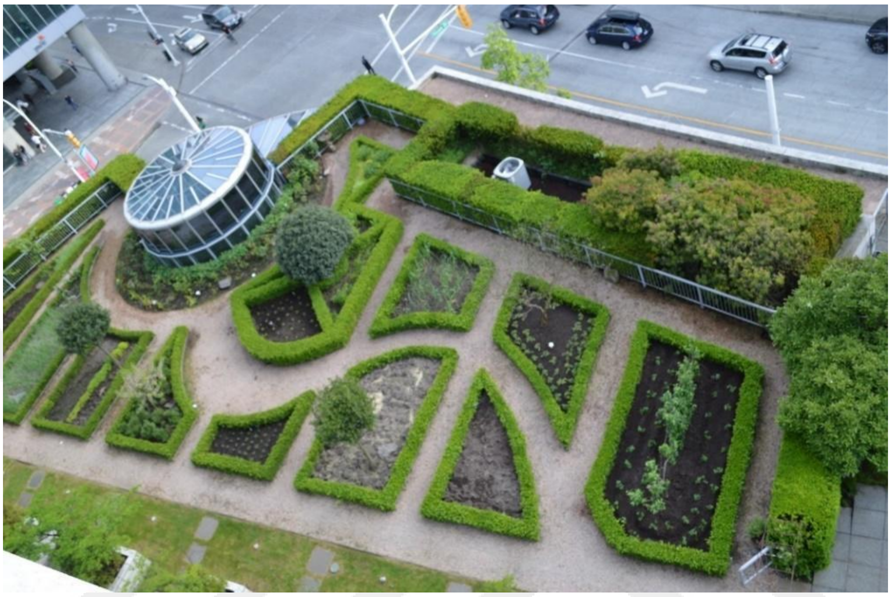


Figure 2.23. Air perspective table on the green ceiling of the hotel (Lena et al., 2009).

It is clear from the foregoing that in this project, the heavy-duty, heavy weight. It provides a variety of uses and diversity of plants and gives great economic benefits, as well as many climatic benefits of the air conditioning in the outdoor seating area, and also reduces the temperature inside the building and provides the beautiful scenery and psychological comfort needed by the recipient in the building (Mohamed and Abdul, 2015).

One of the disadvantages of this project is climate and atmosphere in the city of Canada. Therefore, the plants adapt to the local atmosphere prevailing in the specific area and are unsuitable for the local atmosphere in Iraq because of the environmental difference between the local climate of Iraq and the local climate of Canada. Therefore, plants that adapt to climatic conditions Iraq is a warm dry (Mohamed and Abdul, 2015).

### 2.4.3 L’Oasis d’Aboukir – Paris – vertical garden (2013)

Project Name: L'Oasis d'Aboukir (The Oasis of Aboukir)

Year: 2013

Location: Paris, France

Building Type: Commercial

Type: Living Wall

System: Single Source Provider

Size: 2700 sq.ft.

Slope: 100%

Access: Accessible, Open to Public

Designers/Manufacturers of Record:

Vertical Garden Designer: Patrick Blanc, Le Mur Vegetal

Living Wall System: Dr. Patrick Blanc, Le Mur Vegetal

Blanc made this installation to turn the usual facade of the building in the second district of Paris into a bright green space. It was a demonstration of his conviction that nature can significantly improve the quality of urban space. The installation of L'Oasis d'Aboukir (the name comes from Rue d'Aboukir, where the work is installed) uses 237 plant species diagonally to create a sense of dynamism and movement (Bianchini, 2017).

Figure 2.24. L’Oasis d’Aboukir (Bianchini 2017).

This project completely illustrates the conceptual development of Blanc's work; from the preparty geometric structure (but with fully identified species) to a puzzle-like tessellated pattern, where each plant is carefully placed in its concrete tile (Bianchini, 2017).


Figure 2.25. L’Oasis d’Aboukir a view before the installation (Bianchini, 2017).


Figure 2.26. The oasis of Abukir, a view after the installation (Bianchini, 2017).

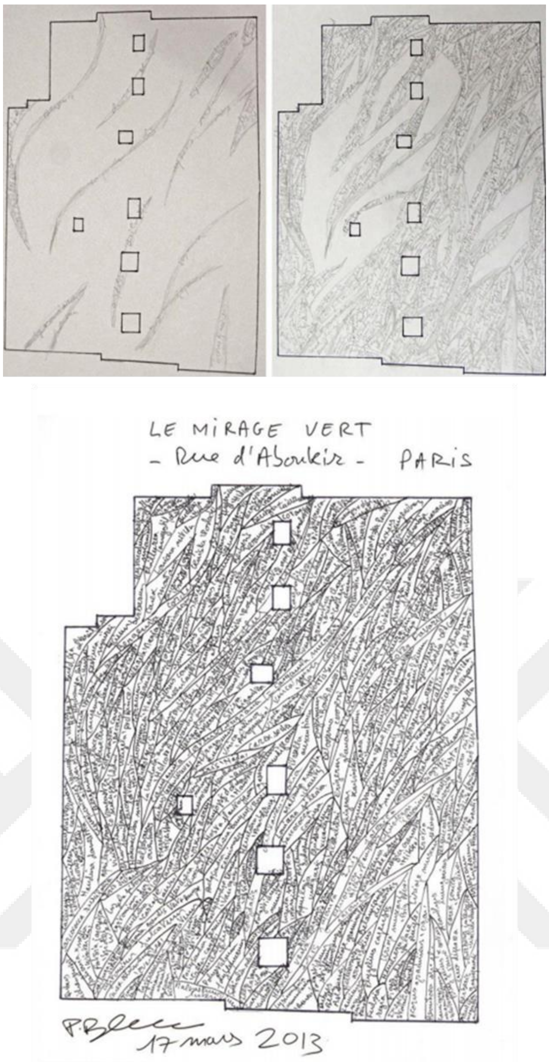



Figure 2.27. The Oasis of Aboukir, development drawings (Bianchini, 2017).

Figure 2.28. oasis of Abukir plant uses (Bianchini, 2017).

### 2.4.4. PAMM Pérez Art Museum – Miami – vertical garden (2013)

Figure 2.29. PAMM Pérez Art Museum – Miami – vertical garden (Herzog and de Meuron, 2014).

Landscape Architecture: ArquitectonicaGEO

Vertical Garden Designer: Patrick Blanc

Irrigation Consultant: Sweeney + Associates

Landscape Contractor: Valley Crest

Design Architect: Herzog & de Meuron

Architect of Record: Handel Architects

General Contractor: Moriarty of Florida

Location: Miami, Florida, USA

Date of Completion: December 2013

Photos: Robin Hill, Julio Espana / ArquitectonicaGEO

Award: Florida Chapter of the American Society of Landscape Architects (FLASLA) Award of Excellence, 2014

Frederic B. Stresau Award – Bestowed upon an Award of Excellence winner that best exhibits absolute innovation and design excellence of the profession in 2014.

For the Pérez Art Museum, Blanc required architects to conceive three-dimensional vertical gardens, rather than two-dimensional (Herzog and de Meuron, 2014). The solution was to make an array of "columns", hanging or self-supporting, from steel pipes wrapped in a felt layer dotted with hundreds of small pockets. Plants, as customary, grow on the felt layer, but architect had to carefully choose them, because one half of the column is exposed to sunlight, strong winds and a saline stream, while the other is constantly in the shade, so he installed different species (80 in general) on the outer and inner sides, using both tropical and native plants. Irrigating is provided by large rainwater, which accumulates the flat roof of the building (Herzog and de Meuron, 2014).

Figure 2.30. PAMM Pérez Art Museum (Herzog and de Meuron, 2014).

Figure 2.31. PAMM Pérez Art Museum Miami; model of the installation (Herzog and de Meuron, 2014).

Figure 2.32. PAMM Pérez Art museum Miami; east facade, rendering (Herzog and de Meuron, 2014).

Figure 2.33. The living columns before and after plant installation (Herzog and de Meuron, 2014).

### 2.4.5. CaixaForum Madrid – vertical garden (2007)

Figure 2.34. CaixaForum Madrid – vertical garden (2008).

Project Name: Caixa Forum Museum Vertical Garden

Year: 2007

Owner: Caixa Foundation

Location: Madrid, Spain

Building Type: Museum

Type: Living Wall

System: Single Source Provider

Size: 6458 sq.ft.

Slope: 100%

Access: Accessible, Open to Public

Designers/Manufacturers of Record:

Architect: Herzog & de Meuron

Green wall Designer & Installation: Patrick Blanc

General Contractor: Ferrovial Agroman

Green wall Consultant: Benavides & Lapèrche

Irrigation Installation & Maintenance: Isla Verde

Green wall System: Le Mur Végétal

The green wall of Caixaforum is supposedly the second most famous project of the architect Blanc. Filled with about 15,000 plants from 250 species, a vertical garden of 6,500 square feet was conceived to provide physical and spiritual relief in the hot summer climate of Madrid (Bianchini, 2017).

Therefore, the plants were chosen to adapt to the specific climatic conditions of the city, located at an altitude of 670 meters above sea level (Bianchini, 2017).

Species installed in the living wall include, among others, Arenaria montana, Bergenia cordifolia, Campanula takesimana, Cedrus deodara, Cerastium tomentosum, Cistus purpureus, Cornus sanguinea, Dianthus deltoids, Garrya elliptica, Kerria japonica, Lonicera nitida, Lonicera pileata, Pilosella aurantiaca, Sedum alpestre, Taxus baccata, Yucca filamentosa, and different Begonias, Fuchsias, Geraniums, Hydrangeas, and Mahonias (Bianchini, 2017).

Figure 2.35. Caixaforum Madrid vertical garden (Bianchini, 2017).

Figure 2.36. Caixaforum Madrid vertical garden, details (Bianchini, 2017).

### 2.4.6 Green roof in park view apartment

This project is an apartment on the top floor of the Park View project in Erbil, it was designed and installed by greenscape group. The project is implemented with minor changes in the types of landings (Anonymous, 2017g). The products used in this project were protection from weeds, wooden edging of the landscape, the ZinCo green roof system, polished pine bark and decorative aggregate (Anonymous, 2017g).

Figure 2.37. Design of project (Anonymous, 2017g).

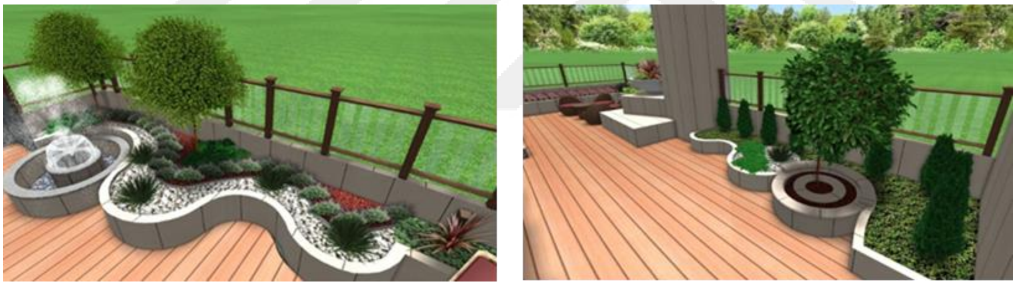


Figure 2.38. Design of project (Anonymous, 2017g).

Figure 2.39. View of project (Anonymous, 2017g).

Figure 2.40. View of project (Anonymous, 2017g).

### 2.4.7. Residential house 1

This project is located in the city of Sulaymaniyah. It was developed and implemented by Greenscape Company in 2015. Landscaping is fully implemented with minor changes. The products used in this project were: green ZinCo roof, automatic irrigation system, weed protection, geotextile, Aluexcel landscaping, permeable green paver, stainless steel water filters, pine bark, decorative mulch and decorative aggregate (Anonymous, 2017g).

Figure 2.41. Design of project (Anonymous, 2017g).

Figure 2.42. Applying project (Anonymous, 2017g).

Figure 2.43. View of project (Anonymous, 2017g).

### 2.4.8. Residential house 2

This project is a residential building located in the city of Sulaymaniyah. It was developed and implemented by Greenscape in 2014. Landscape design is fully implemented with some changes in the types of landings (Anonymous, 2017g).

Figure 2.44. Design of project (Anonymous, 2017g).

The products used in this project were ZinCo green roofing, weed protection, geotextile, geomembrane, Aluexcel landscape edging, root protection, water cascade with LED lighting, decorative stainless-steel balls and decorative aggregate (Anonymous, 2017g).

Figure 2.45. View of project (Anonymous, 2017g).

## 3. MATERIALS AND METHODS

### 3.1. Materials

#### 3.1.1. Study area

The study was conducted in Erbil which is the capital city of Kurdistan Region/Iraq. Erbil is located in the north of Iraq on 36.19° North 44.01° East (Figure 1). According to UNESCO (2010), historically Erbil is considered one of the oldest uninterruptedly dwelled in cities in the world. It is believed that the urban life in Erbil is dated back to at least 6000 BC (Rasul and et al., 2016). The surface area of Erbil is approximately 130 km2. The population of Erbil urban area was 1,025,000, in October 2008 which makes it one of the biggest cities in Iraq (Rasul et al., 2016). Erbil is located in a comparatively plain area. Moreover, on average Erbil is elevated about 426 meters above sea level (figure 3.1) (Rasul et al., 2016).

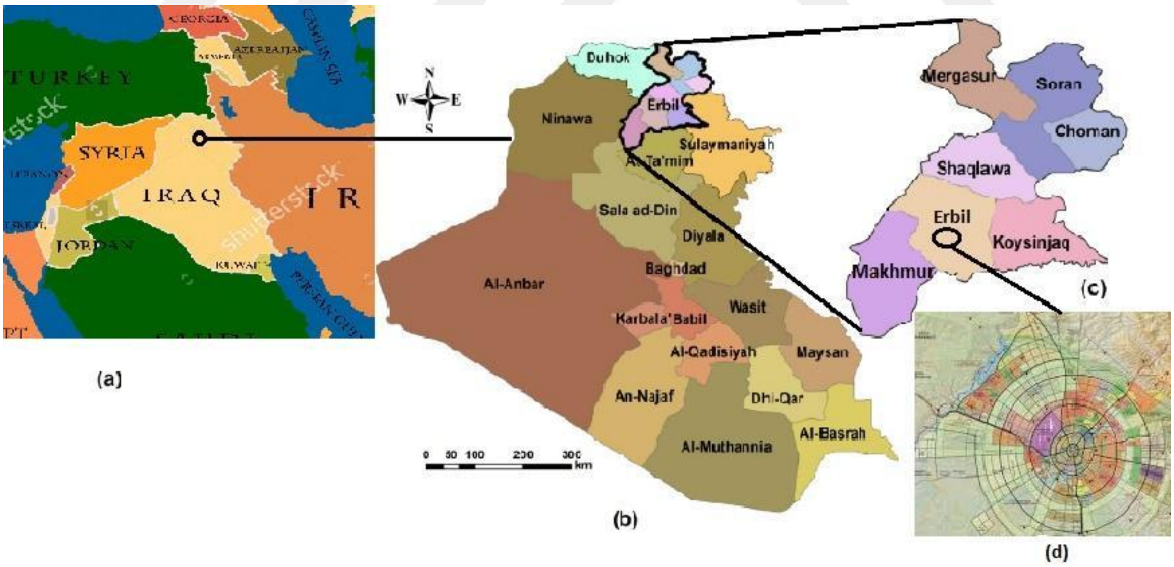



Figure 3.1. Displays the map of the study area.

#### 3.1.2. Erbil climate

Erbil's climate is hot-summer Mediterranean (Csa) according to Köppen climate classification, with very hot summers and cool wet winters. January is the wettest month, there is rain in winter more than summer in Erbil.The average temperatureis 20.2 ° C per year, and average precipitation is 543 mm (Anonymous, 2017h.).

### 3.1.3. Wind

Throughout the year, Erbil experiences the regular hourly wind speed in slight seasonal diversity. May, June, July, August and September are the windiest months of the year. The average wind speeds during this period are higher than 6.0 mph. Furthermore, 22 of July is the windiest day of the year, with an average hourly wind speed of 7.2 mph. from October to April are considered calmer period of year in comparison to other months. Nevertheless, 6 of January is the calmest day of during year. The average hourly wind speed in that day is between 5 to 6 mph (Anonymous, 2017h).

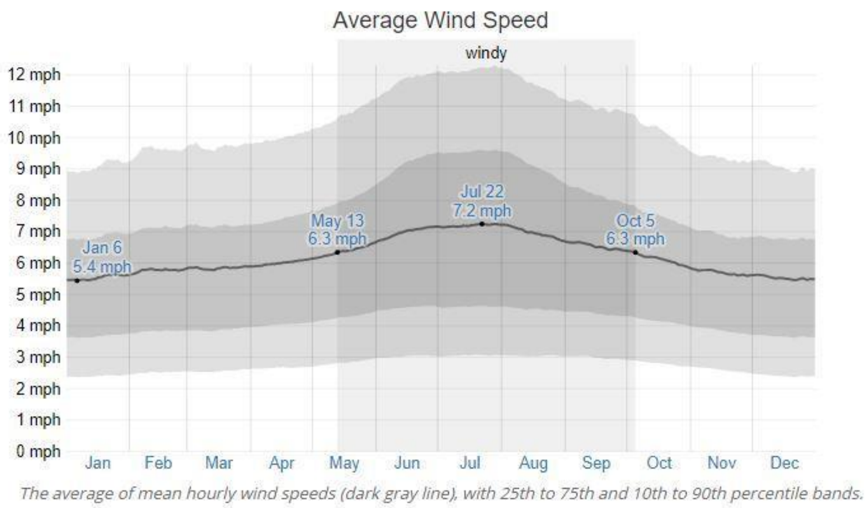
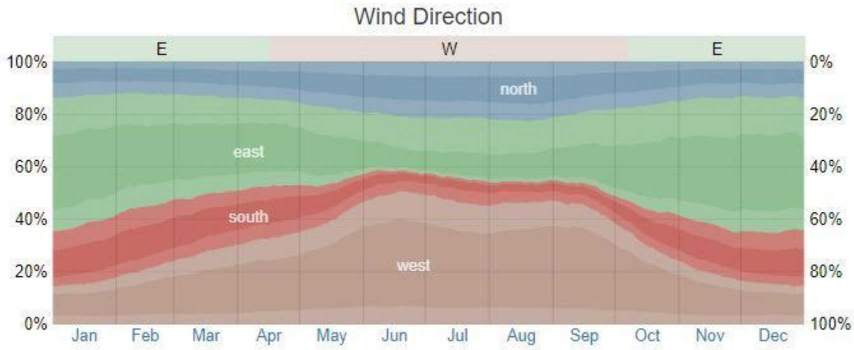



Figure 3.2. Displays average wind speed in Erbil (Anonymous, 2017h).

During the course of the year the main average hourly direction of wind differs in Erbil. Usually, from the mid of April to the beginning of October the wind is from the west, 18 of June has a peak proportion of 51%. However, from beginning of October to the mid of April frequently the wind is from the east, the January the first has peak proportion of 51% (Anonymous, 2017h).




*The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions (north, east, south, and west), excluding hours in which the mean wind speed is less than 1 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).*

Figure 3.3. Demonstrates the wind direction in Erbil (Anonymous, 2017h).

### 3.1.4. Rainfall

The summer table (Figure 3.4) indicates the percentage of rainfall in the city of Erbil and most of the province. It is obvious that the minimum precipitation rate in the last year was (417.3) mm. In addition, the rate of rainfall in the rest of the province of Erbil was (847.7). While the minimum percentage of rainfall was recorded in the Erbil plain (304) mm, the highest rainfall was recorded in the Mergasur area (1391.1) mm (Anonymous, 2017h).

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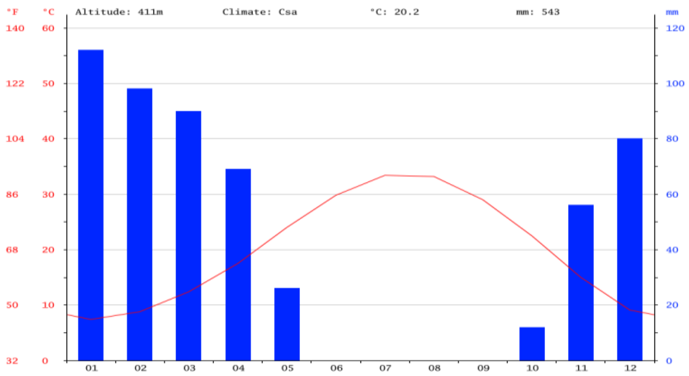


Figure 3.4. Displays climograph of Erbil (Anonymous, 2017h).

### 3.1.5. The site locations of the research project

In the present study, three buildings that are located close to the citadel were investigated.

### 3.1.6. The Mayor Office building

This building is located in Erbil city center closed to the citadel. It is also located near local market which is one most crowded area in city.


Figure 3.5. Shows the location of Mayor Office Building**.**

This governmental building was constructed in 1921. It is a historical building which consist of two floors. It has usually been used for administration works for the locals.

Figure 3.6. Shows Mayor office building in different time periods **(**Anonymous, 2017p)

### 3.1.7. Machko tea shop

The second building that has been studied in this research is Machko café. This building is located in the city center of Erbil precisely next to the main entrance of Erbil citadel and in the surrounded by a big market.

Currently, this building is considered a part of citadel its traditional tea shop usually is full of tourist and other people. This historical building was constructed in 1940. It consists of two floors with big balcony.


Figure 3.7. Exhibits the location of Machko Café.

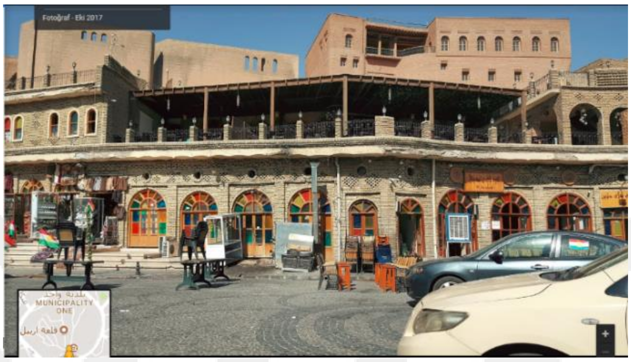

Figure 3.8. Shows Machko Café **(**Anonymous, 2018l).

### 3.1.8. Erbil tower hotel

The third and the last building in this research is the Erbil Tower Hotel. This building is located in city center in highly busy area near to citadel and Doctor's Street in Erbil.

This building is composed of eight floors which divided into three different sections. The first or the ground floor is used as market. Furthermore, the second floor is mainly utilized as an office floor. Finally, the remaining floors (six floors) are employed as a hotel. This old hotel was built in in the late 1950s.


Figure 3.9. Demonstrates the location of Erbil tower**.**

Figure 3.10. Shows the Erbil Tower **(**Anonymous, 2014m).

## 3.2. Methods

### 3.2.1. Software programs

In this research three different software programs were applied.

#### 3.2.1.1. AutoCAD 2014

AutoCAD is a computer assisted designing program for drawing that supports the construction of two dimensional and three-dimensional graphics. Since the beginning of 1980s, The AutoCAD has been developed as an application for personal computers. This program is accessible as a web application since 2010. It can be operated via browsers and smart phones. In this research the AutoCAD 2014 was applied for drawing geometric plates very precisely and quickly in a short time.

#### 3.2.1.2. 3DMax 2015

This software is one of the most influential software for three-dimensional design. This software generates an environment to work on a large land and produces images as the user imagines and changes them from a three-dimensional viewpoint like constructing buildings, generating vehicles or others. This software, which is created by Autodesk, is mainly a 3D modeling, animation and rendering program for 3D objects. In current study, this software was applied for modeling project of the research.

### 3.2.1.3. Lumion

Lumion is a software that utilized for producing three dimensional models. This program is more beneficial in working with materials, rendering and lightings in comparison to the Scots, the Max, the Maya or the AutoCAD. To be more explicit, it is a decent program for encoding, rendering and video work in a very simple and wonderful way. This software has realistic features for modelling of trees, vehicles, birds and humans. In addition, this program offers an advantage for moving people or animals, which might be required to be added to the project and dealing with water, fountains and other natural supplements such as dust, hay or tree leaves to give a real impression of the project. In this study, Lumion 6 was applied to add landscape Martials and rendering.

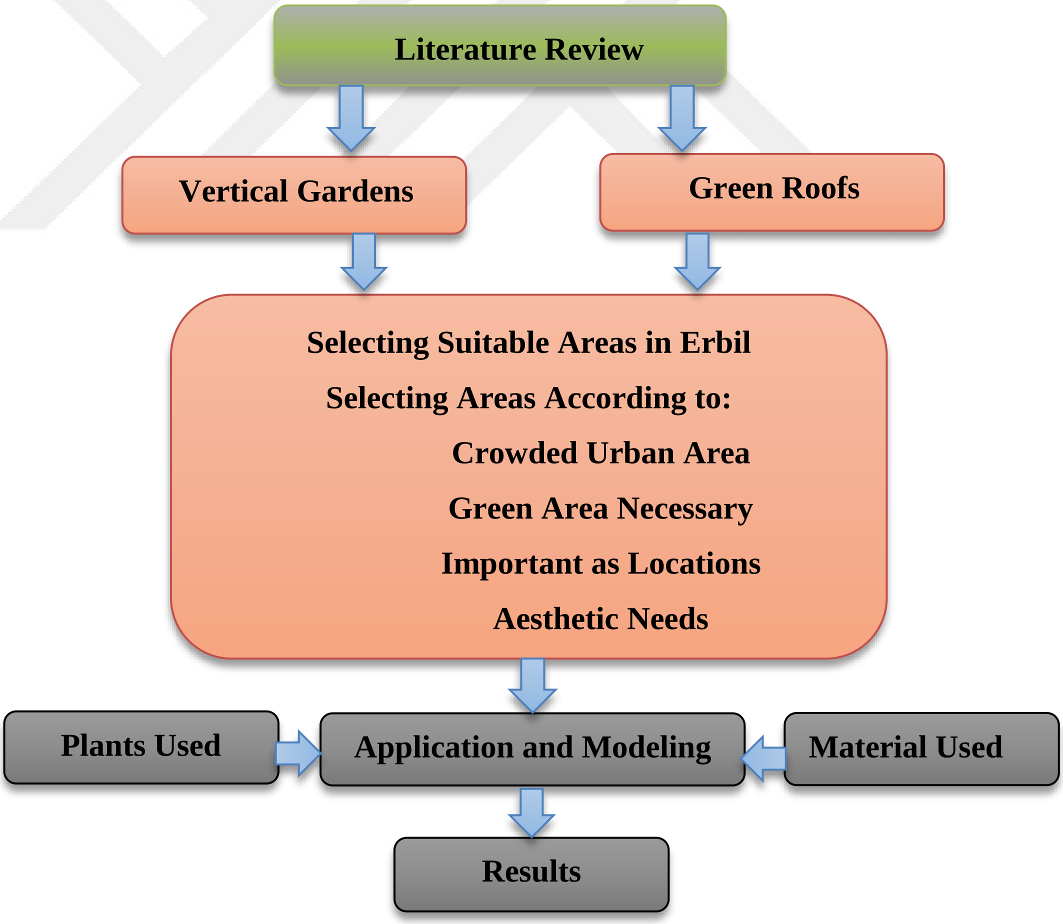


Figure 3.11. The summary of material method.

This study consists of five different chapters: i) Literature review, ii) Vertical Garden and Green roof, iii) Selecting Suitable Areas in Erbil, iv) Application and modeling, v) Results.

### 3.2.2. Literature review

In this chapter the well-known and successful cases are focused on. In addition, the achievements, important points, advantages and disadvantages related to this project are covered. Moreover, examples that associated with the design application in this research, the world and local experience is studied such as roof gardens and vertical garden.

### 3.2.3. Green roofs and vertical gardens

This chapter focuses on the green roof with two different type intensive and extensive design. Furthermore, the designing, structuring, properties, advantage and disadvantage of these two types of green roof are studied to acquire substantial information that will need in the next steps for designing and applying.

In addition, the vertical garden both green wall and green façade are studied to identify the most appropriate approach to our study area.

### 3.2.4. Selecting suitable areas in Erbil

In this chapter the three sites or buildings are selected. The process of selecting these buildings is in accordance to mass buildings, intensive population and insufficient green areas. All the investigated sites are selected in or nearby city center of Erbil and around Erbil city citadel because the importance of location which anyone who visits Erbil can easily reach it.

### 3.2.5. Application and modeling

This chapter focuses on the designing and modelling of the project. The designing concept was obtained from combining novel forms and Erbil historical heritage. In addition, this chapter also describes the materials and plants that were utilized in the study. The modelling is done by using two computer software such as 3D Max and Lumion.

### 3.2.6. Results

The final chapter presents all the findings from the other steps. The purpose of this chapter is to analyze results from proposal rendering and other significant information for getting best recommendation on how the green roof and vertical garden in Erbil can be applied. In addition, it is also for identifying the optimum location for applying green roof and vertical garden and how to design to provide more aesthetic for Erbil city.

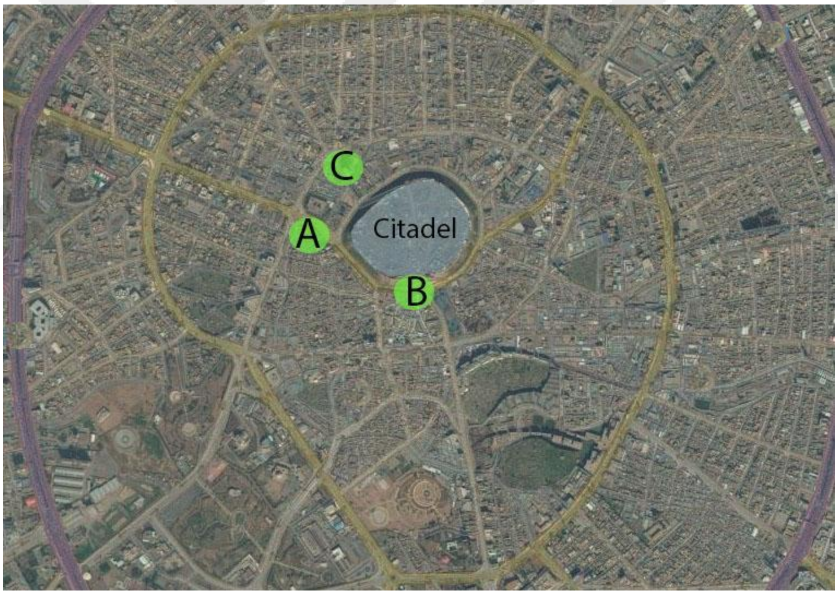


Figure 3.12. Displays the three selected sites.

#### 3.2.6.1. The Mayor Office Building

This building has been utilized for governmental purposes. It is located at city center of Erbil near big market and Erbil citadel. The area highly crowded and lacks of green zone. the air pollution in the area is caused by cars, building mass and high population density. This area necessitates green spaces more than other part of city to deal with this contamination. The green spaces cannot obtain by removing and changing the buildings to green spaces around this area because almost all the buildings are historical. This issue can be solved by applying state of art technology to add green to roofs and walls without removing the existing building.

Another reason for choosing this building is that there is no green space belongs to the building the administrating people who work there they don’t have space to spend their free time for taking a rest, drinking a tea or smoking …etc.

This building is directly located at the street thus it does not have free space for green site. However, the building has decent space for applying green roof and creating a garden in a top of building. This will accomplish our necessity for green space in the city and building.


Figure 3.13. Shows the Mayor office building.

### 3.2.6.2. Machko tea shop

This is the second investigated building in this research. This building also located in city center next to the entrance of citadel surrounded by huge market. Even though there are a few green spaces in front of the site, it is not sufficient to cope with the high level of air pollution that he area which are caused vehicle, mass buildings and electrical generators (especially in summer).


Figure 3.14. Displays the roof of the building and citadel gate (Anonymous, 2018l).

The location of this building is very important as there are a lot of tourists visiting the citadel. From (Figure 3.14), it can be seen that the roof of the building is completely neglected and mistreated. It is clear that the roof is utilized for water tank, electric generator …etc. This can have a negative impact tourism sector. Nonetheless, it can be solved ecologically by applying green roof technique.

### 3.2.6.3. Erbil tower hotel

This tower is located in most crowded area at Ainkawa (Doctors Street) and behind the citadel. A glance at the site, green spaces are not found around the building. As this street is mostly visited by patients, green space is highly important psychologically. The addition of vertical green to the building, partly accomplished the required green space for the city and psychologically assist in the treatment of patient visiting this street.


Figure 3.15. Showing crowded area around Erbil Tower.

This tower has an old Iraqi architecture style which was very famous style in that period. The building was designed by architect Rfaat chadrche. Currently, this building is used as hotel but does not have any architectural values.


Figure 3.16. Showing old Iraqi architecture style Erbil Tower.

Nonetheless, via adding vertical green, the original architecture value of the building can be returned. This building is very important in Erbil elevation as it can be seen in different views at city center.

# 4. RESULTS AND DISCUSSION

## 4.1. Site Analysis

### 4.1.1. The mayor office building

This building is located in Araban district north west of Erbil citadel. The historical houses of the Araban district is directly located behind the building. In the south of building there is small garden, a mosque and big market. In addition, the Erbil governorate building is at the opposite of the building. At the north of the building are computer shops and a street called Sultan Mozafar Street. Finally, the front is Qala Street which connects the center and citadel of city to Kurdistan parliament and Sami Abulrahman Park, which is the biggest park in Erbil.


Figure 4.1. Shows Mayor building with surrounding area.

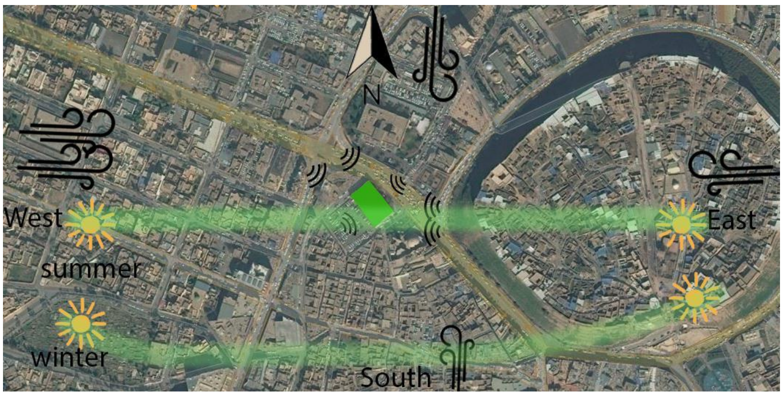


Figure 4.2. Demonstrates the site analysis.

### 4.1.2. Machko café

This building located at Qala (Citadel) district in front of the citadel and surrounded by a big market (Bazar). A small green space called Shar Park is at the opposite of the building. In the front Qala Street which is turn around citadel, opposite is Karkuk Street.


Figure 4.3. Demonstrates Machko café building and the surrounding area.

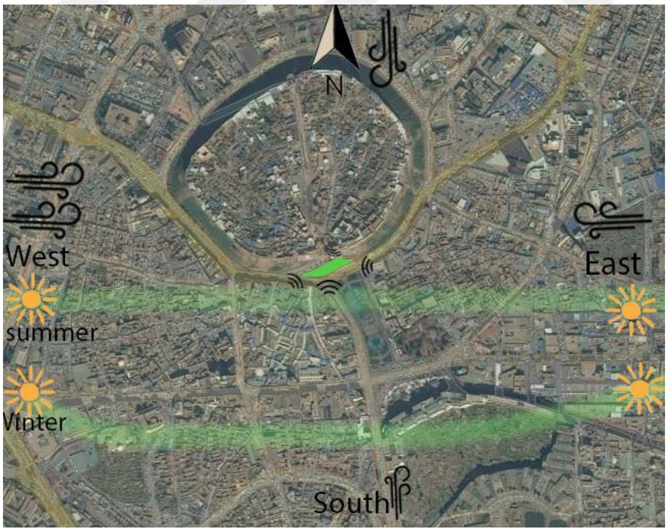


Figure 4.4. Shows site analysis.

### 4.1.3. Erbil tower hotel

This building is located at Mustafwfi district north of citadel at Ainkawa (Doctors) street. Shex Mahmoud around about is in front of the building. At the opposite, are medical and doctor offices.  There is a free area behind the building that is projected to be a museum of Erbil.

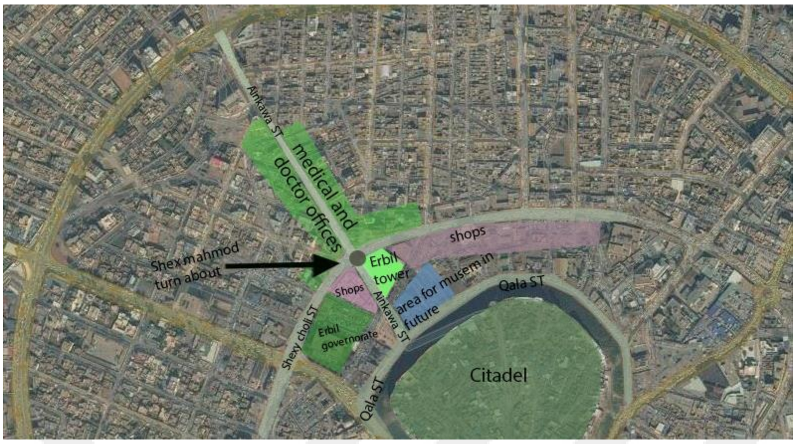


Figure 4.5. Exhibits Erbil tower building and the surrounding area.

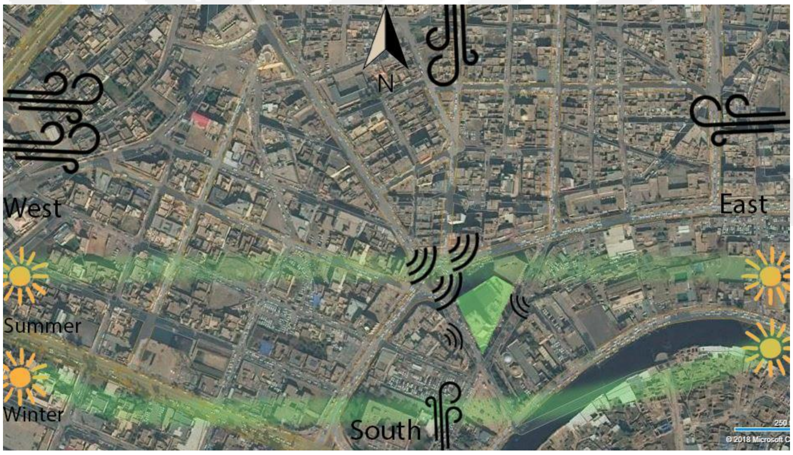


Figure 4.6. Shows site analysis.

### 4.2. Swot Analysis

#### 4.2.1. Erbil Mayor building

- Strength

1. The location of the building is very important as it is close to city center and located in very important street that connects the city center to another important sector.
2. The building has rugged constructed which mainly constructed from stone and concrete that is suitable for applying intensive garden roof.

3. The building is historic and also located in a historical district.
4. Closeness to the Erbil citadel, make the building precious element in area.

Figure 4.7. Displays citadel view from the site.

● Weakness
1. Crowded area.
2. Crowded traffic.
1. Because it is directly located on the street, it has less security and privacy of building.
3. Less of site landscape.

Figure 4.8. Shows the building and the area around it.

- Opportunity

1. The building can be used as a museum in future.
2. The building can be used to revive that areas because it is close to historic areas.
3. It can be used as a tourism attraction because it is very close to the Erbil citadel.

Figure 4.9. Shows historical building around the site (Anonymous, 2017o).

- Threat

1. Not paying attention to old buildings.
2. Destroying building and changing it to new commercial building.
3. The historic buildings in this area are neglected.

Figure 4.10. Demonstrates a historical building rebuilt with new building (Anonymous, 2014n).

### 3.2.2. Machko tea shop

- Strength
2. Machko café is very famous in Erbil
3. The location of Machko is very important as it is located in front of citadel gate and regarded as a part of citadel.
4. Currently, the building is recognized as a cultural café and almost all tourists visit the area.
5. The building has historical heritage.

Figure 4.11. Shows the outdoor sitting around Machko café (Anonymous, 2018l).

- Weakness
1. Crowded area because it is close to the market (bazar).
2. The Structure of the building is not very strong.
3. Neglecting the roof of building and using it for water tank, electrical generators and wastes.

Figure 4.12. Roof Machko cafe (Anonymous, 2018l).

- Opportunity

1. It can be used mainly as a part of citadel.
2. The building can be used like a tourist attraction.
3. The roof of the building can be use the green roof to attracting more tourists for the building and the citadel.
4. The roof or the building can be used as a resting area for the people visits the citadel.

Figure 4.13. Shows visitors from citadel gate and Machkos' roof (Anonymous, 2018l).

- Threat

1. The roof of building is used for water tank and electric generator which have dangerous impact on the building.
2. The structure of the building requires rehabilitation or renovation to keep it safe.
3. The location contaminated and crowded.

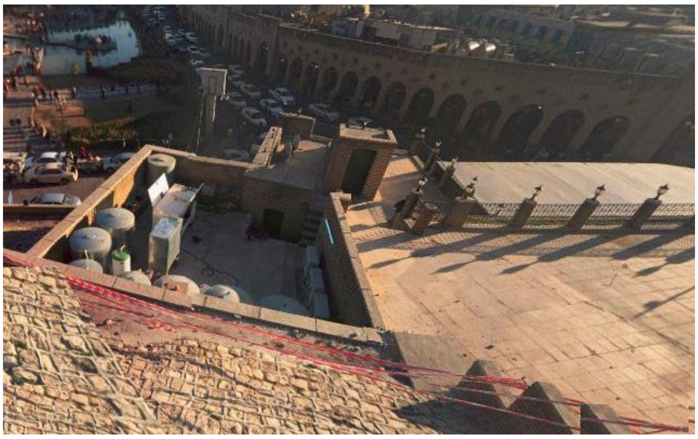

Figure 4.14. Show the roof of the building which used for tank and generator (Anonymous, 2018l).

### 4.2.3. Erbil tower hotel

- Strength

1. Erbil tower is one of the highest building in the city center
2. It is a famous building.
3. It can be seen from almost every place in Erbil city.
4. It is located in very important location, near the Erbil citadel.
5. It is characterized by its historical architecture.

Figure 4.15. Displays the building view from citadel (Anonymous, 2014m).

- Weakness

1. Very crowded area.
2. Rods around the building are narrow and crowded.
3. The building does not have any gardens or green spaces, and it is directly located on the street.

Figure 4.16. Shows view from citadel (Anonymous, 2014m).

Figure 4.17. Shows the building and the surrounding area (Anonymous, 2017r).

- Opportunity

1. The building is one of the historical building in Erbil.
2. It is located near the Erbil citadel and the museum which is planned to be built in the near future.
3. It has an old architecture style.
4. It can be considered as a part of the Erbil citadel.
5. It can be used like historical place for attracting tourists.

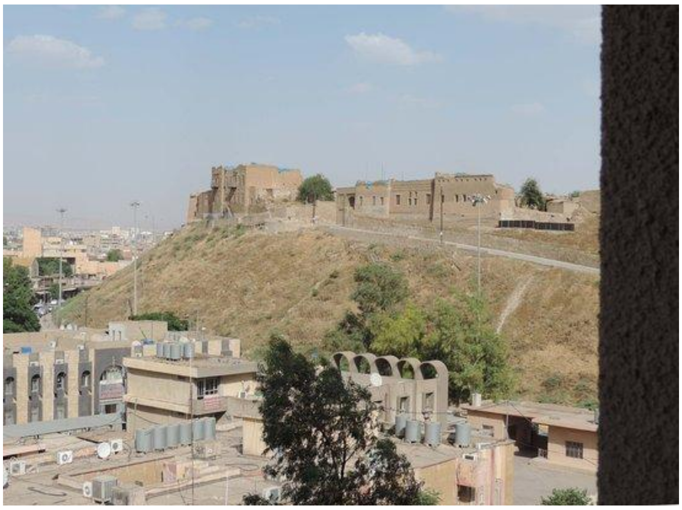

Figure 4.18. Shows citadel view from building (Anonymous, 2014m).

### 4.3. Finding

### 4.3.1. The mayor office building

#### 4.3.1.1. Designing concepts

This building has formal lives; Therefore, informal designing approach was preserved, first at all, requirements of the people who are a sign this building was considered İn this extent short time recreation places were established.

Figure 4.19. Project top view.

The roof is designed in intensive green roof as two axes. The first one is the main axis that connected the roof to the rest areas. The second axis is moving through inside the plants and flowers section. There are two courtyards on the roof, the courtyards are made of glass to not to obstruct transparency between zones and parts of the roof. This will reflect on the relationship between government employees and the locals.

Four rest areas are designed, two of them are shaded by umbrellas and other two zones are shaded by tress. Because of the hot weather in Erbil city, one of shaded zones has water fountain which provide mad a fresh air for the area.

There is a small cafeteria inside the building that can be used for roof section. The roof is designed to give more comfortable feeling to visitors, employees and locals by using informal and organic form in concept and using natural material like stone and wood in the pathways.


Figure 4.20. Describes the utilized materials in the project.

### 4.3.1.2. Plants and flowers

After researching and studying the garden roof and planting in it, the different type of plants and flowers are used in the case study. The plants and flowers are selected according to the followings: -

- Suitability with the roof garden and low soil.
- Suitability with the weather and situation in Erbil.
- Required minimum amount of water.
- Shading necessary and aesthetic.

Because trees required more soil and resistance wind, they are planted in pots. *Robinia pseudo acacia'* is used for shadow in places around sitting area. *Vitis vinifer'* is used in pergola also it is giving shadow in sitting area.

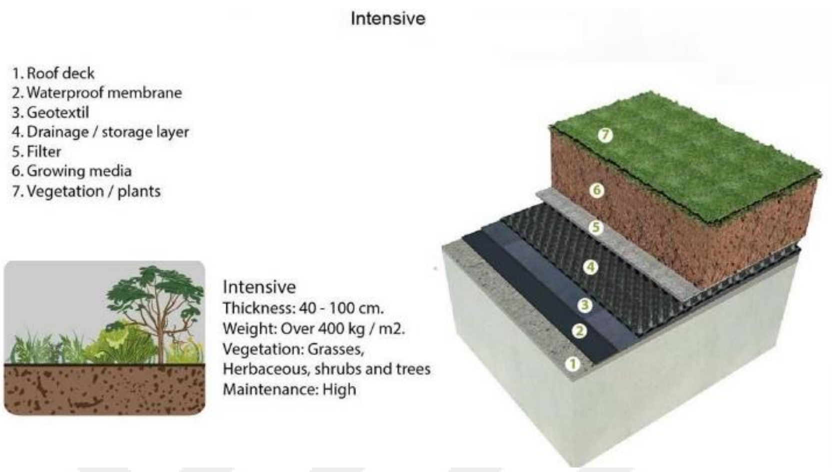


Figure 4.21. Intensive green roof detail (Anonymous, 2012k).

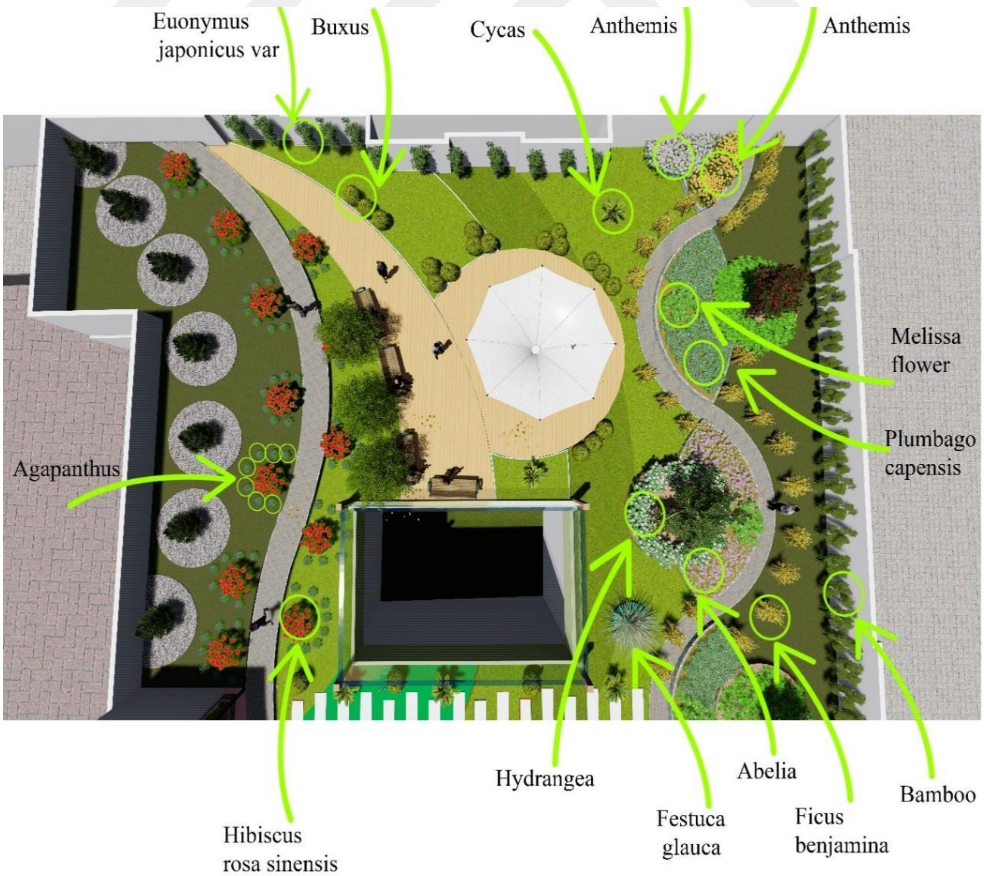


Figure 4.22. Shrubs plant used in project.

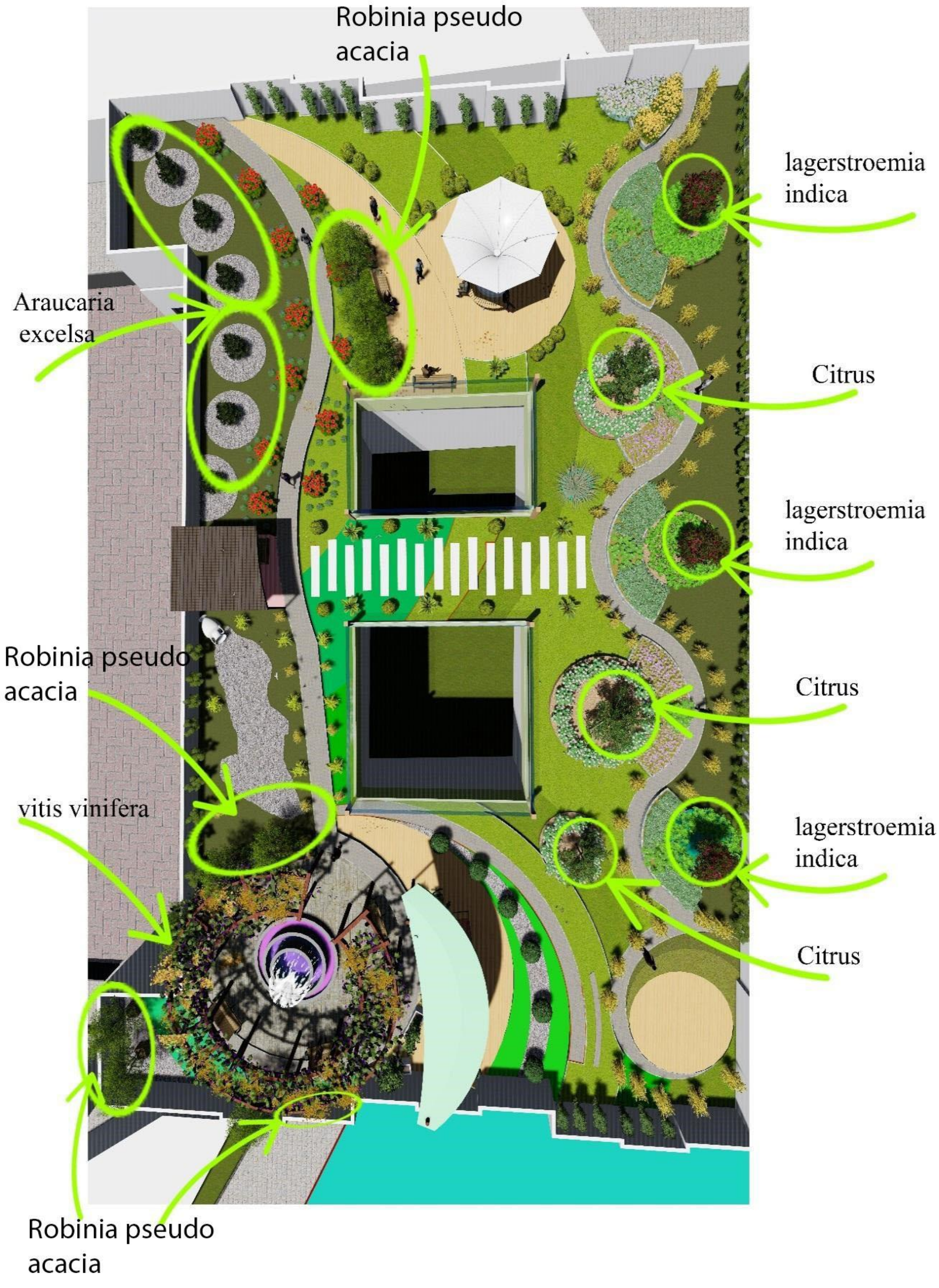


Figure 4.23. Tree plants used in project.

The *Citrus'* plant is also used in the design as it is very suitable for Erbil environment and garden roof as it mentioned in the literature review.

*Lagerstroemia indica'* with the pink flowers is used in design to make the roof more attractive. *Araucaria excelsa'* pine is used in the design because it is suitable for garden roof and using white gravel gives more attraction.

*Hydrangea'* flower with blue color is used in the circle around *Citrus'* that balances between tree and flower elements. *plumbago capensis'* and *abelia'* flowers are used around *melissa'* in consecutive order. *Bamboo'* and *euonymus japonicus var'* are planted straightly against the wall. *Anthemis'* flower is planted with yellow and pink colors to give vibrant colours. *ficus benjamina'* is planted in the second axis pathway. *Agapanthus'* and *hibiscus rosa sinensis'* with red color are planted within groups around main axis pathway. *hedera helix'* is planted near entrance to cover the wall. *Buxus'* is planted in groups and one by one with Cycas'. The *Cycas'* plant expresses power for these types of formal buildings.

Table 4.1. Plants used in project

| Plants name | color |
|---|---|
| *Robinia pseudoacacia pictum* | |
| *Vitis vinifera* | |
| *Plumbago capensis* | Blue |
| *Hydrangea* | |
| *Citrus* | |
| *Bamboo* | |
| *Anthemis* | White |
| *Anthemis* | Yellow |
| *Lagerstroemia indica* | Pink |
| *Melissa flower* | |
| *Abelia flower* | White |
| *Ficus benjamina* | Yellow |
| *Euonymus japonicus var* | |
| *Araucaria excels* | Blue |
| *Agapanthus* | |
| *Hibiscus rosa sinensis* | Red |
| *Hedera helix* | |
| *Buxus* | |
| *Cycas* | |
| *Festuca glauca* | Blue |

Figure 4.24. View from south and SE.

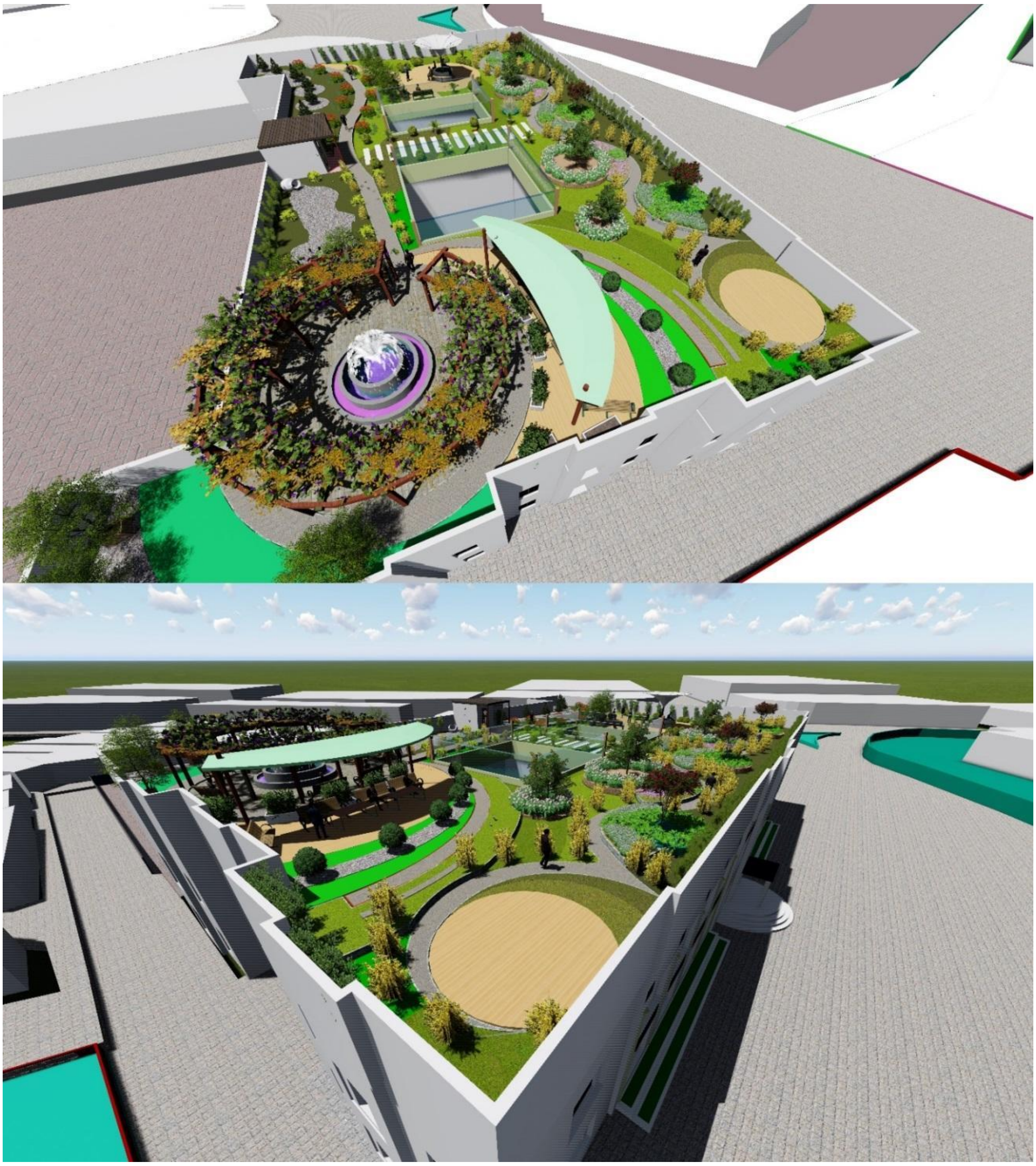

Figure 4.25. Views of project.

Figure 4.26. Views inside the project.

Figure 2.27. Views inside the project.

Figure 4.28. Views inside the project.

#### 4.3.2. Machko tea shop

The extensive green roof design was applied to the building because the roof is different levels. Wood is the main material that used for all pathways and sitting areas because it has a lightweight and does not affect the structure of the building. The siting area is designed in a different places and zones, it can be entered to project from citadel gate, Machko café shop and old citadel rod. The main space is designed to be accessed directly from the entry from the citadel. It has a fountain in the middle of the space and has a good view from citadel and Shar Park.  From the front is green roof and from the two side are green roof thus it is very important to provide a rest area so as people coming from citadel and the cafe below.

The circle space is designed as sitting area that shaded by trees and a fountain. This circle symbolizes the shape of Erbil city that all districts are located around citadel and the citadel is located at the middle of city center. The other sitting place is designed at lower level that has a good view to Shar’ park. new roof has been added to the store so that it does not impact the project. the new ceiling and the seating area are designed. Two photograph’s areas are designed, the first one has a sitting area shaded by trees. The second one is designed with straight bridge to taking pictures with I ♡ ERBIL’ and other views. The Kurdish regional government flag is designed in the slop with the Turf block and grass. Writing I ♡ ERBIL and the governmental flag make beautiful view of project and attract people from far away.

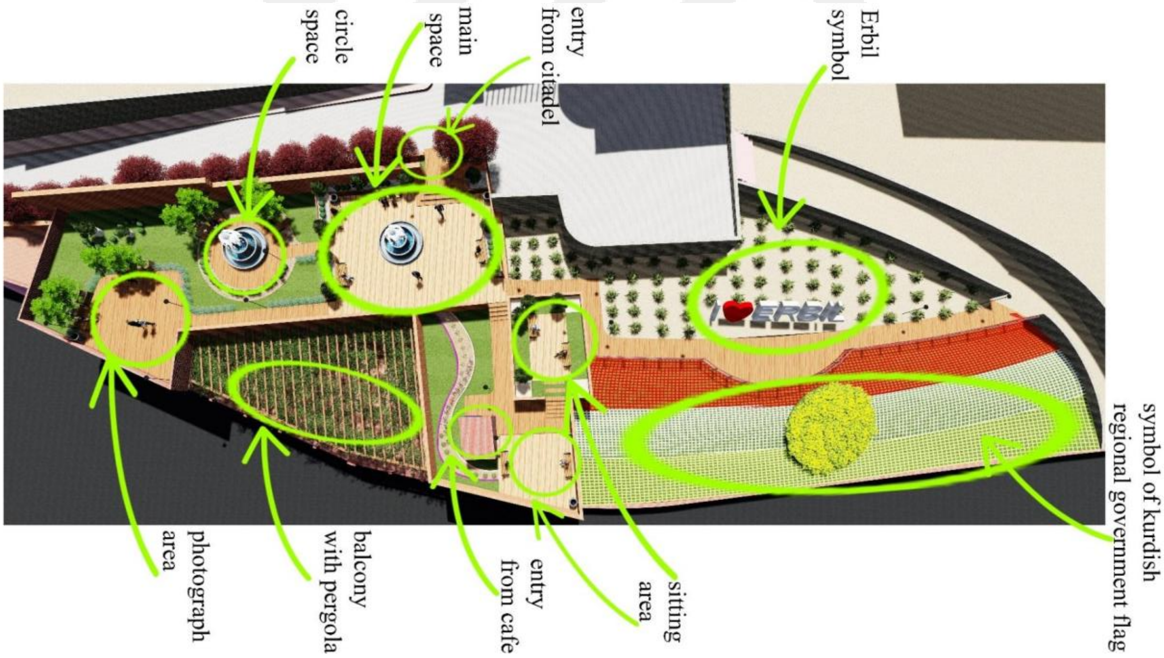


Figure 4.29. Functions of project.

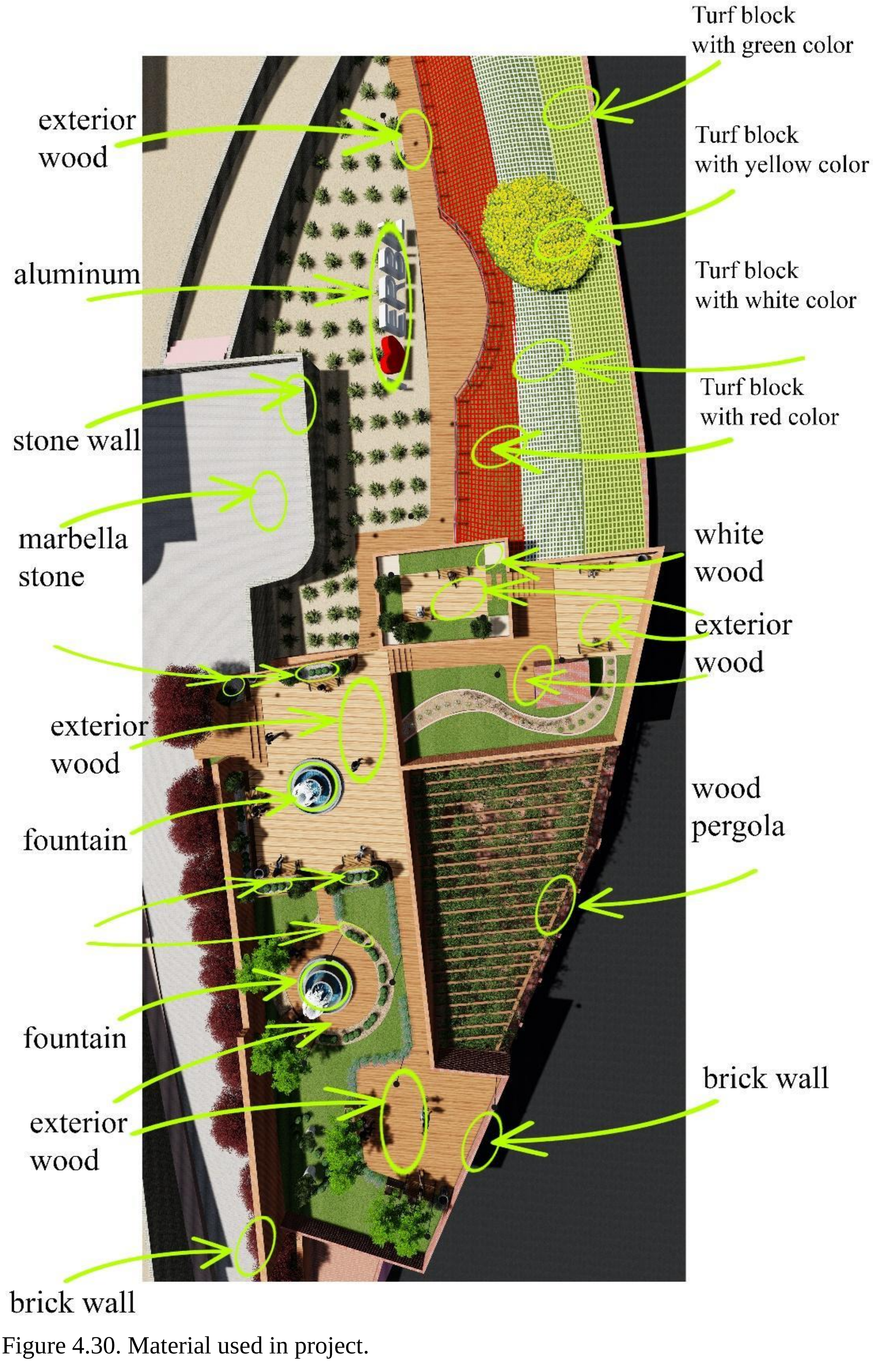


Figure 4.30. Material used in project.

#### 4.3.2.1. Plants and flowers

Subsequent researching and studying suitable plants are selected for the case study. Because the system of the roof is extensive green roof all trees and sharps require pots just flowers and grass are directly planted.

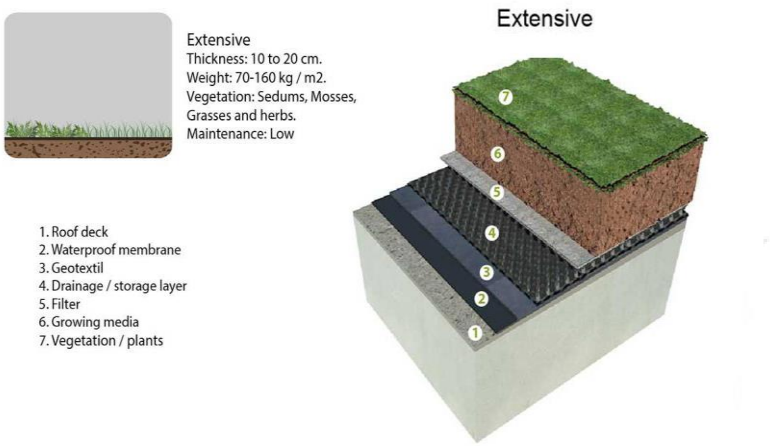


Figure 4.31. Extensive green roof detail (Anonymous, 2012k).

#### 4.3.2.2. Trees and Shrubs

*Prunus Cerasifera Pissardii Nigra*' plant is used straight outside wall of the building as this plant is suitable for Erbil whether. It has red color which balances with color of citadel and plays a good role in attracting people to the project. Cupressus *Arizonica'* is planted around sitting area of main space and around sitting area in store roof. This plant is characterized by its suitablity in green roof projects. *Buxus sempervirens'* plant is used between two *Cupressus Arizonica'* plant and around circle space, the shape of the plant is made balance between planter and Cupressus *Arizonica'*. *Juniperus horizontalis'* is planted in slope around I ♡ ERBIL symbol because this plant is covering soil horizontally and protecting the soil from erosion. *Robinia pseudoacacia'* is planted in circle space and photography area for shading because it providing a good shading especially in the afternoon. *Hedera helix'* is planted at the wood pergola of the balcony of machko's cafe.

Dry garden is planted in below roof. In this part, plants that have the ability survive in dry or arid weather like an *Opuntia ficus-indica'* and *Trichocereus pachanoi'* at the middle *Echinocactus grusonii'* and *Gymnocalycium'* are planted. *Lavandula'* with purple color is planted around the main space and photography area, which make the project more attractive. *Euryops'* flower is planted in the sun symbol of Kurdish flag inside Turf blocks.

Table 4.2. Plants used in project

| Plant name | Color |
|---|---|
| *Prunus Cerasifera Pissardii Nigra* | Red |
| *Cupressus Arizonica* | Blue |
| *Buxus sempervirens* | Purple |
| *Robinia pseudoacacia* | |
| *Juniperus horizontalis* | Blue |
| *Hedera helix* | |
| *Opuntia ficus-indica* | |
| *Trichocereus pachanoi* | |
| *Echinocactus grusonii* | |
| *Gymnocalycium* | |
| *Lavandula* | Purple |
| *Euryops* | Yellow |

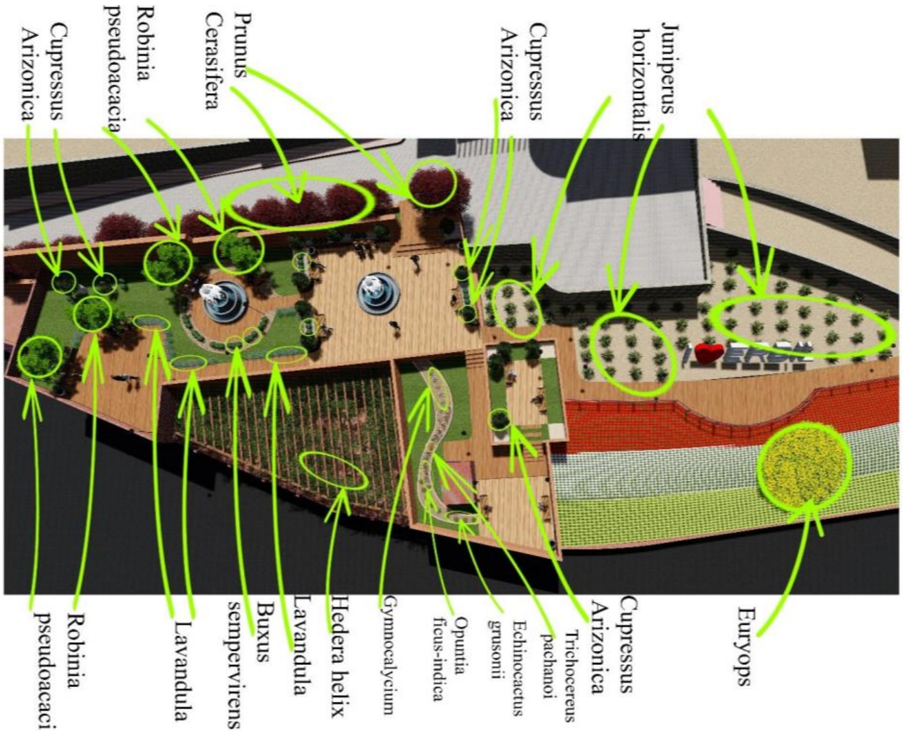


Figure 4.32. Plants used in project.

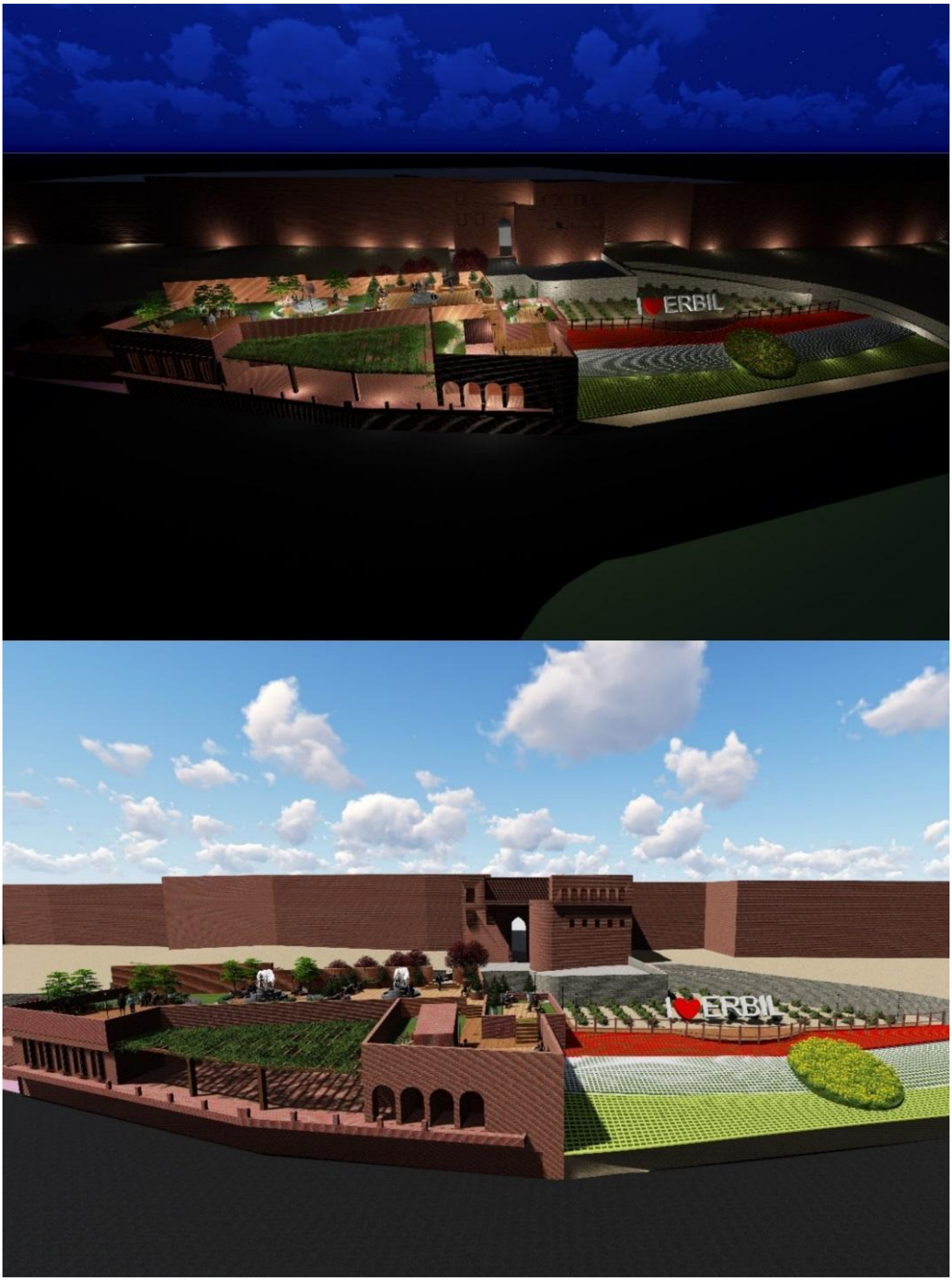


Figure 4.33. Views of project in day and night time.

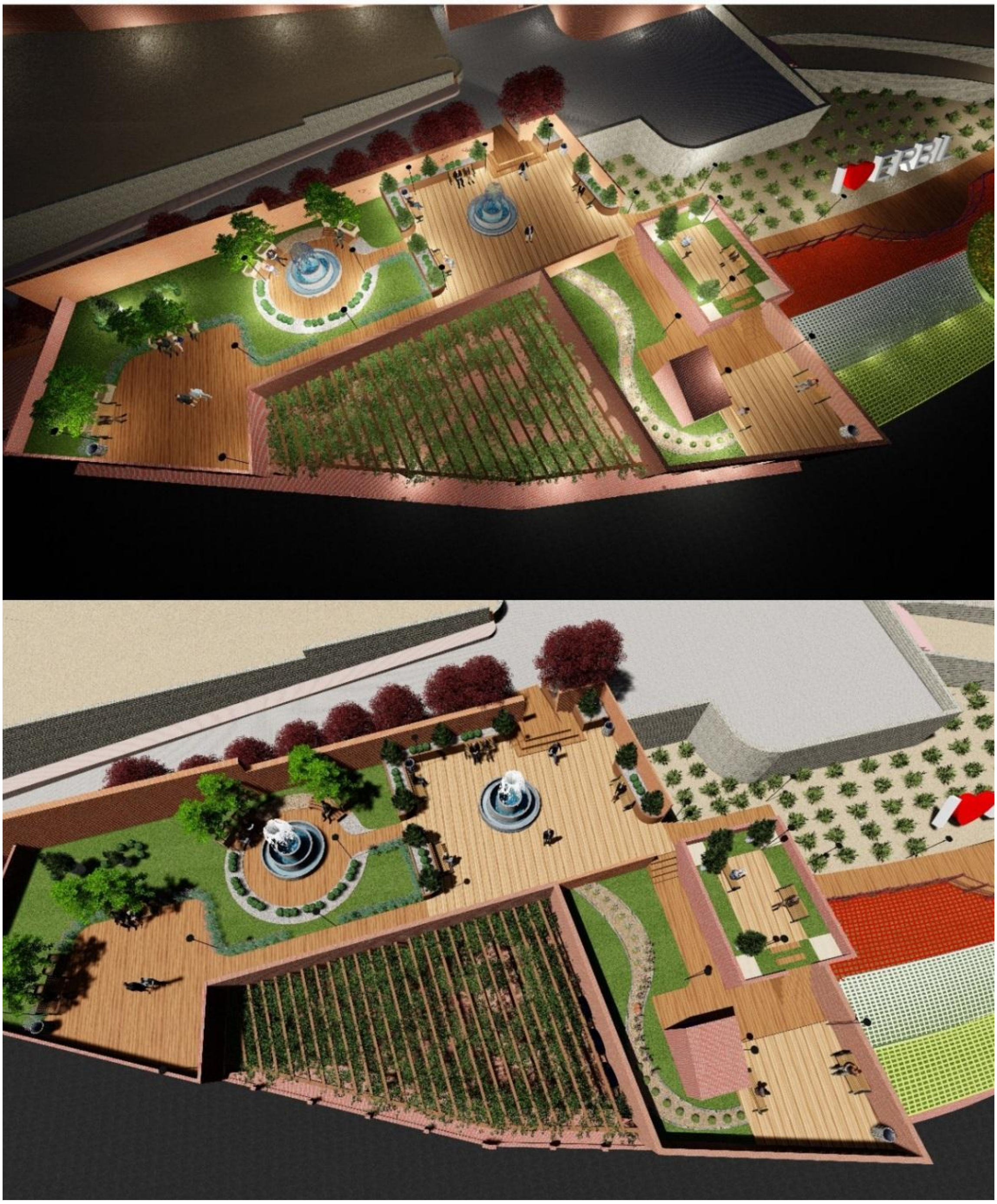


Figure 4.34. Views of project.

Figure 4.35. Views inside the project.

Figure 4.36. Views of project.

Figure 4.37. Views of project.


Figure 4.38. Views inside the project.

Figure 4.39. Views of project.

### 4.3.3. Erbil tower hotel

The green face and green wall are designed for the tower. While green wall technique is applied for balconies, green façades are applied to the other parts. The designing concept consists of different layers that present different nationality and different civilization who have lived in Iraq or Mesopotamia land. Different layers with different colors and plants are combined on one plate reflecting a long and peaceful live together.

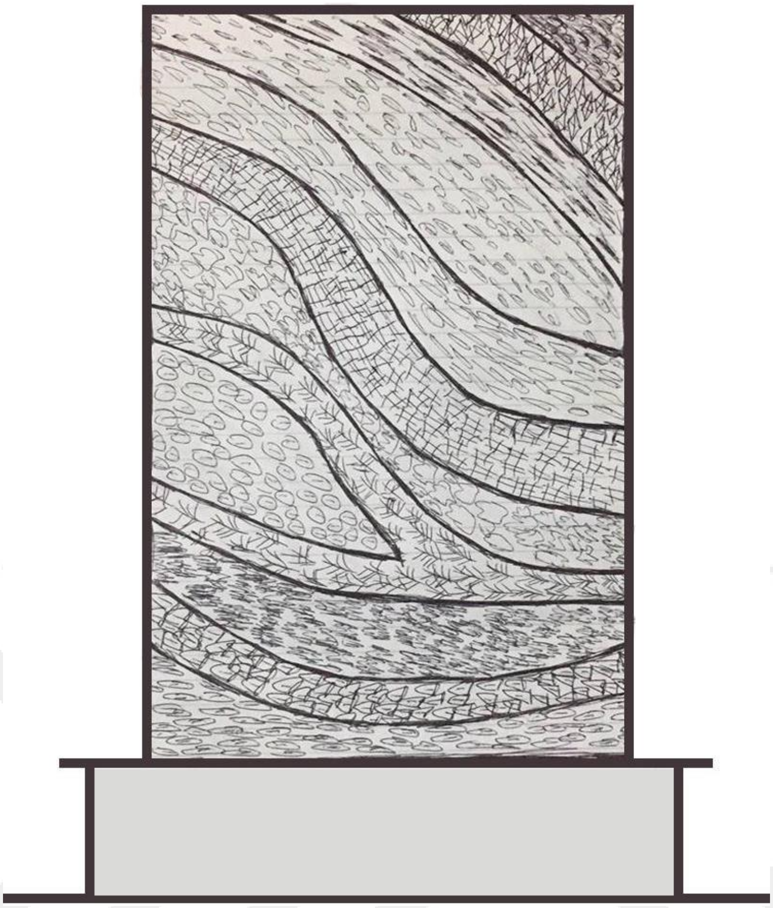

Figure 4.40. Sketch of project.

Both sides of the building from south and north have no windows, they are just concreted face. The green façade and green wall are designed to cover these two parts.

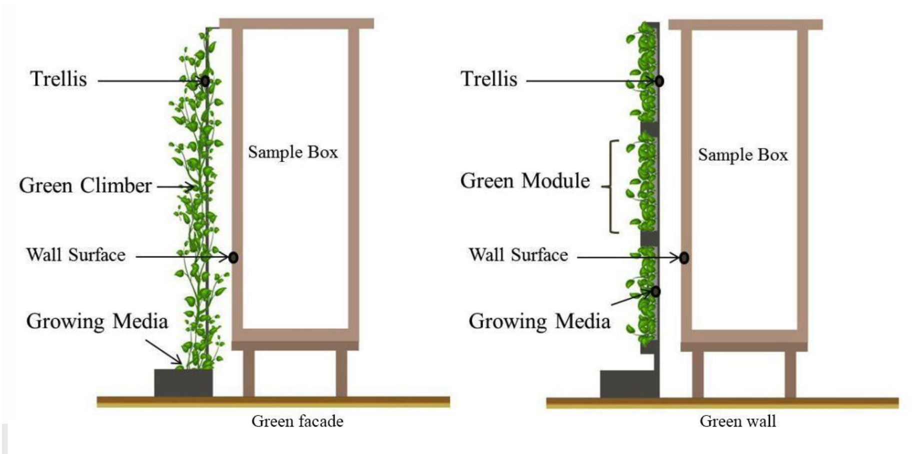


Figure 4.41. Sample detail of green façade and green wall (Safikhani et al,.2014).

The project is firstly serving as a cover for the building. By covering a huge surface of the building with green plants, it protects the building from the sun and heat and makes it more sustainable and beautiful view

#### 4.3.3.1. Plants and flowers

*Codiaeum variegatum pictum', Epipremnum sp, nemorosa' (*purple), *Pteris cretica'* and *Begonia'* (blue) plants are used in the balconies as a green wall.
*parthenocissus quinquefolia', Parthenocissus tricuspidata', Toxicodendron radicans', Campsis Radicans', lonicera japonica' Hedera hilex, hedera helix elegantissima'* and *hedera helix variegata'* are used like a green façade with different layers.

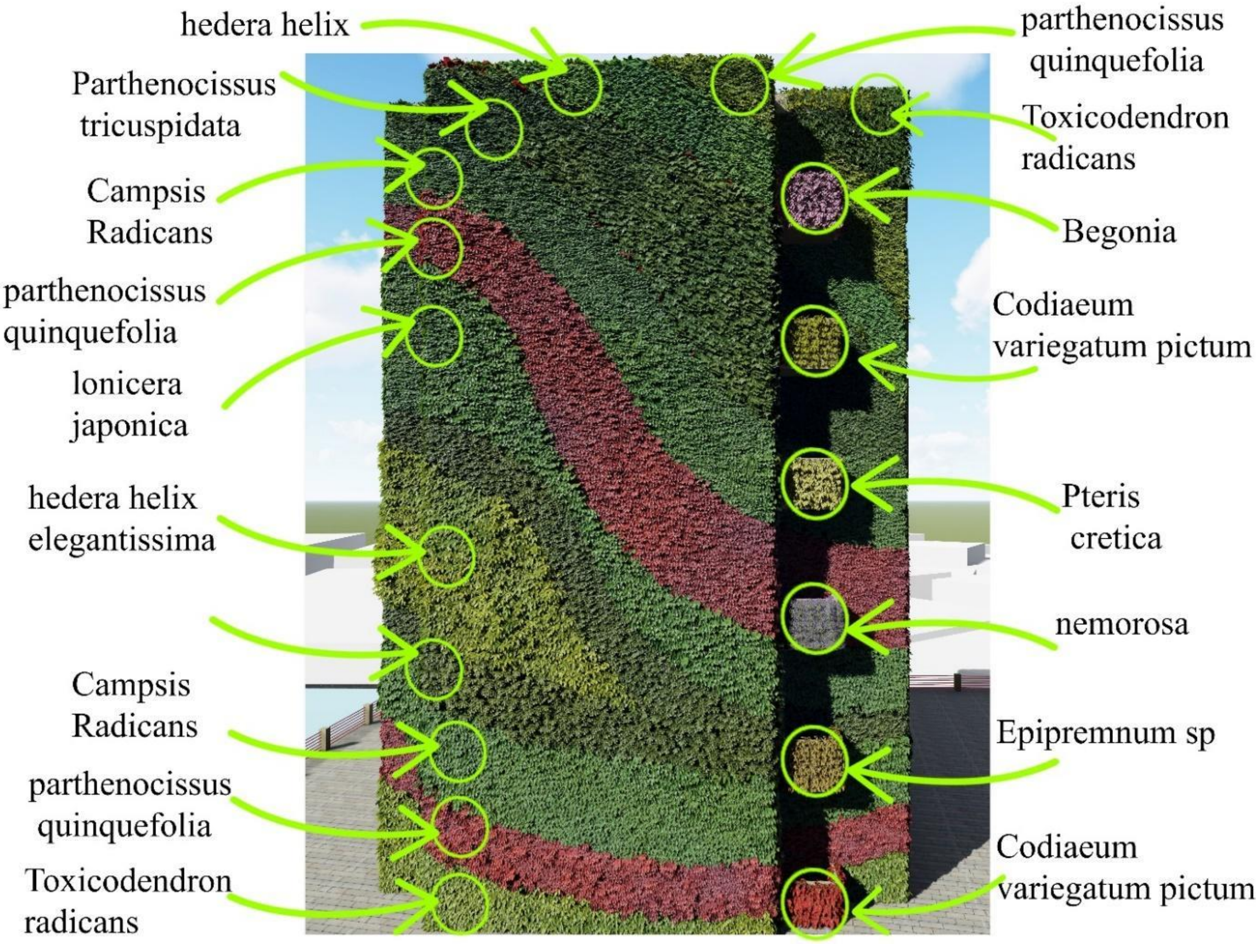


Figure 4.42. Plants used in project.

Table 4.3. Plants used in the project

| Plant name | color |
|---|---|
| *Codiaeum variegatum pictum* | |
| *Epipremnum sp* | |
| *Nemorosa* | Purple |
| *Pteris cretica* | |
| *Begonia* | Blue |
| *parthenocissus quinquefolia* | |
| *Parthenocissus tricuspidata* | |
| *Toxicodendron radicans* | |
| *Campsis Radicans* | |
| *Lonicera japonica* | |
| *Hedera hilex* | |
| *Hedera helix elegantissima* | |
| *Hedera helix variegate* | |

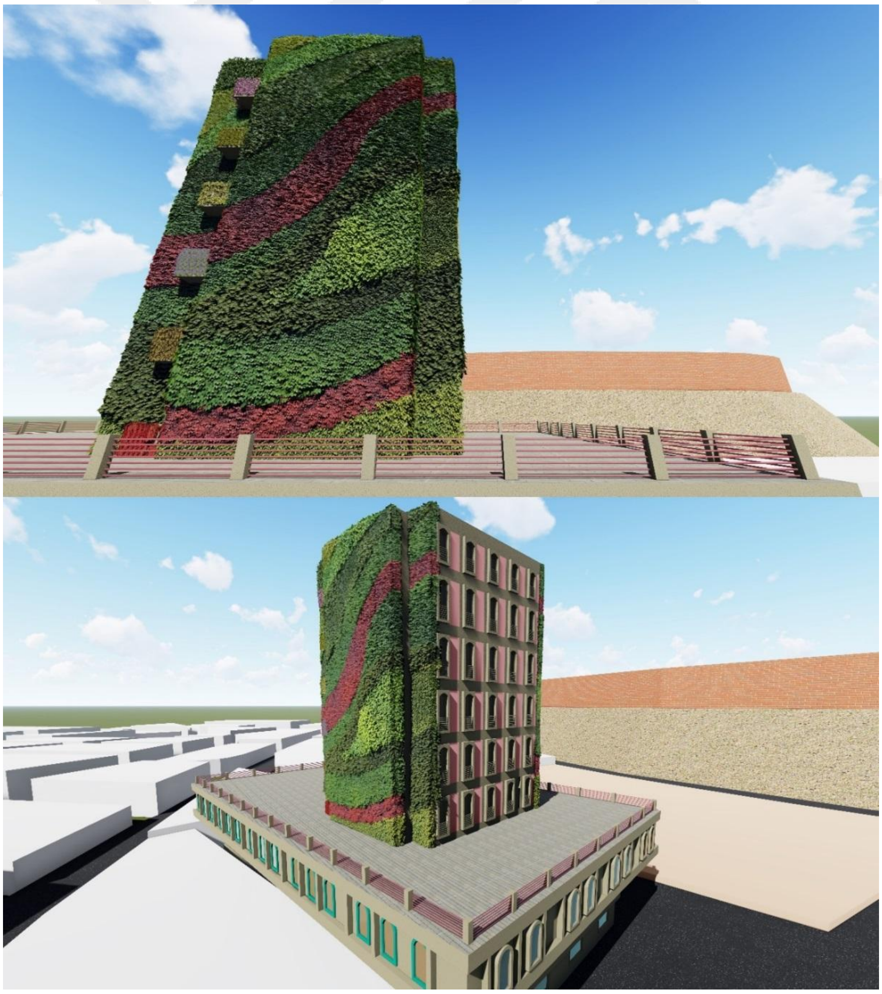

Figure 4.43. Views of project.

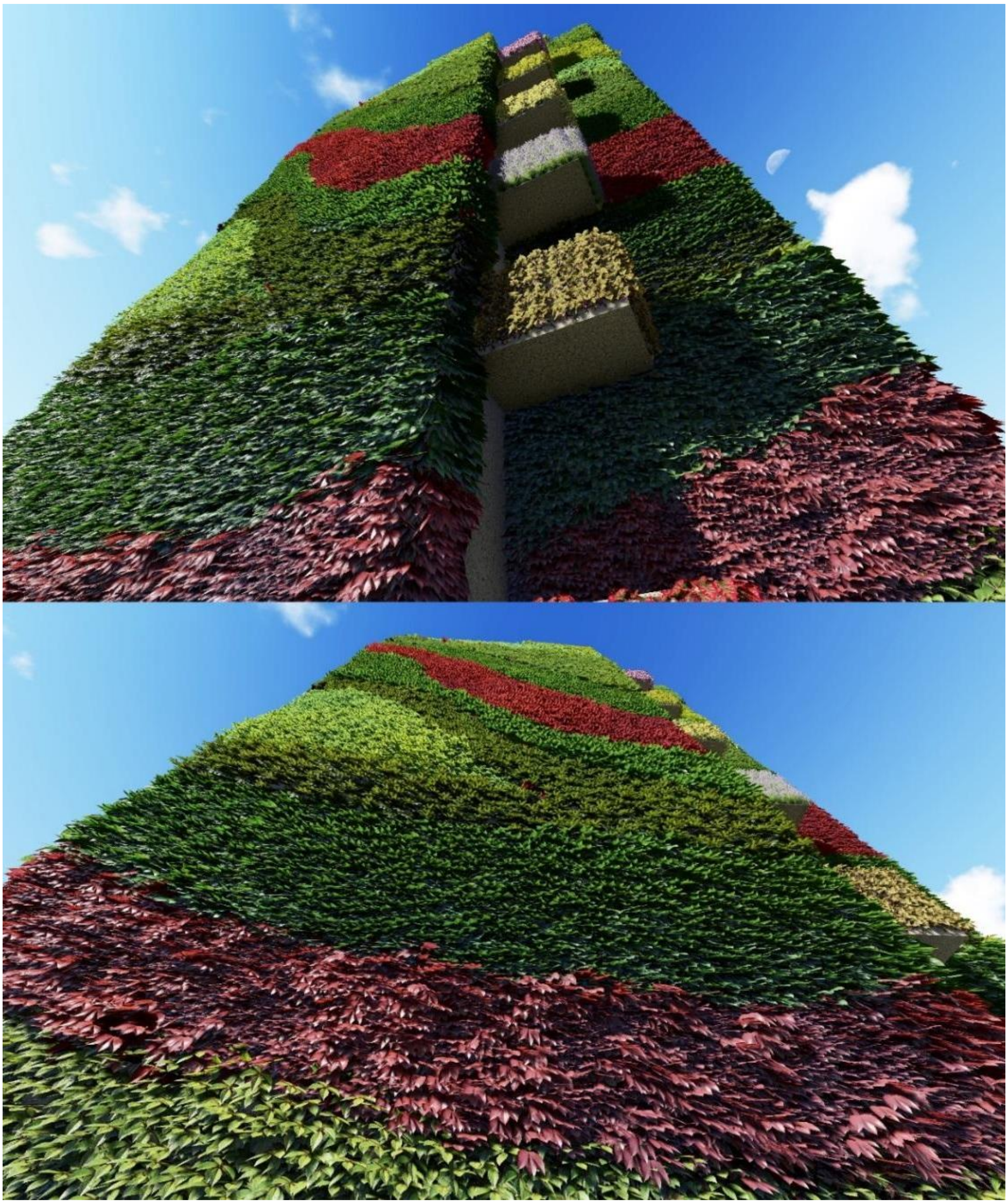

Figure 4.44. Views of project.

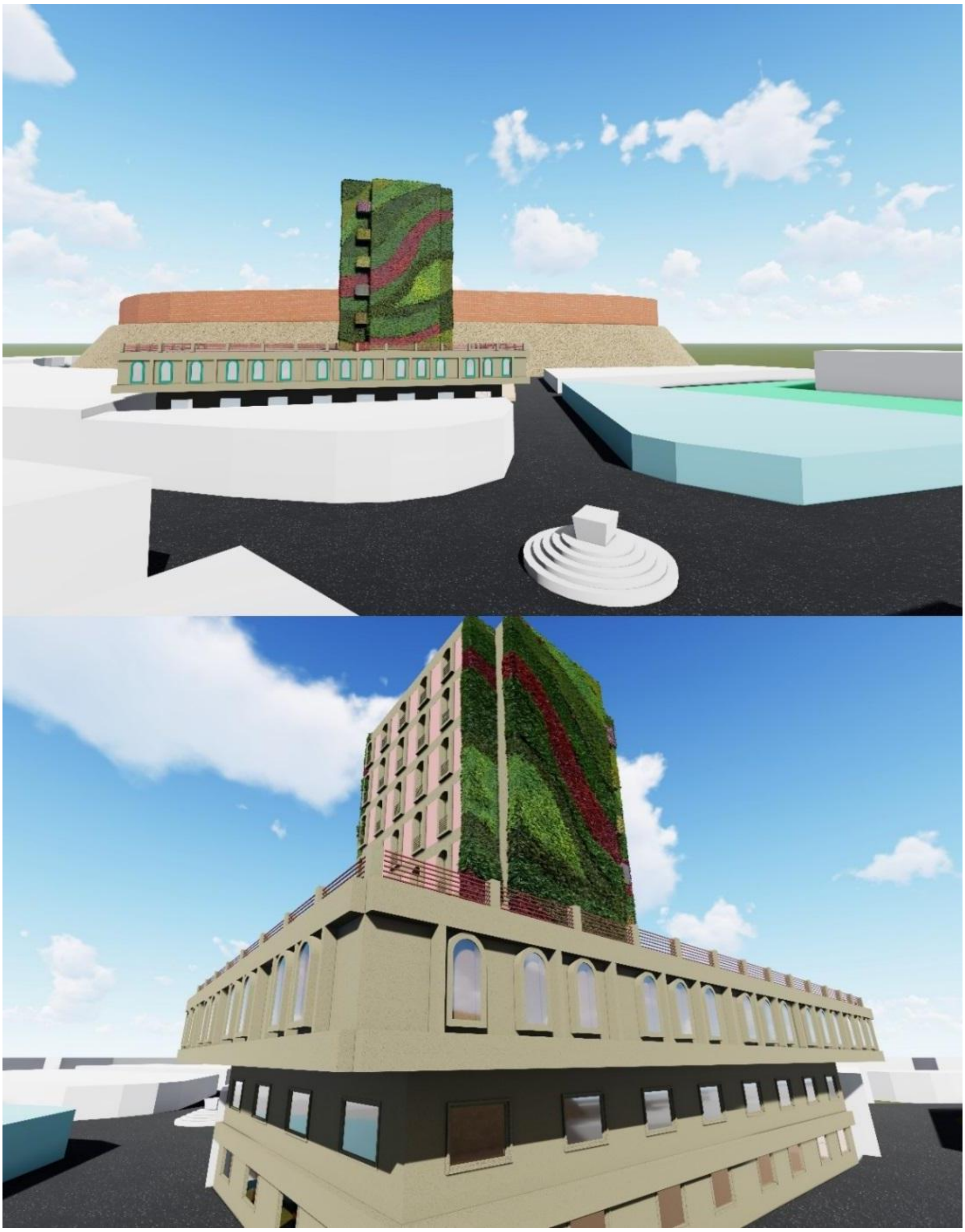

Figure 4.45. Views of project.

## 5. CONCLUSION

Uncontrolled population growth, living migrations, industrialization and environmental pollution and consumption of natural resources are contemporary problems. In the face of these problems; roof gardens and wall gardens are one of the environmentally-friendly solutions that have existed since the past but developed with today's conditions. Roof gardens play an important role in creating a natural habitat in cities with their ecological and recreational functions and increasing the amount of green space per capita in the city. Landscape architectural discipline also plays an important role in the design process of this technology. Roof gardens and wall gardens offer the opportunity to use roofs that are not commonly used in buildings, for energy efficiency, storm water management, sound insulation and aesthetic enhancements.

As a result, roof gardens are not used in Erbil's urban planning, despite all its benefits. As the city of Erbil meets many environmental problems due to its dense population, roof gardens and wall gardens must be applied to the urbanization process. Local governments should place greater emphasis on green roofing and encourage building owners to transform traditional roofing into living roofing.

In this way, most of the problems such as the urban island heat effect in the summer of Arbil people, the high air pollution in winter, and the image pollution due to intense and unplanned urban planning can be reduced and the city can be improved both aesthetically and ecologically.

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***VFgCPMTMi_Bo-WRhno5CuWxD0aSIXibJhU%3Dw203-h114-k-no!7i5312!8i2988!4m5!3m4!1s0x400723009e8ec063:0x81e9838d1f29058d!8m2!3d36.1867531!4d44.0128872.*** accessed: 25.05.2018.

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**EXTENDED TURKISH SUMMARY**
**(GENİŞLETİLMİŞ TÜRKÇE ÖZETİ)**

**ÇATI VE DİKEY YEŞİL YAPILARIN İNCELENMESİ VE ERBİL'E ÖRNEK UYGULAMA**

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## 1. ÖZET

Hızlı yerleşim artışı ve kentsel gelişim, doğal habitatı devasa mühendislik yapılarına dönüştürür. Bu kentsel gelişme, insan refahı ve kentlerin sürdürülebilirliği açısından risk oluşturan çevresel ve sosyal endişelere neden olmaktadır. Nüfus yoğunluğu ve inşa hızı kentlerdeki yeşil alanların hızla azalmasına neden olmaktadır. Beton, asfalt, metal yapılar gibi materyallerden dolayı kentsel bölgeler yapay özelliklere sahip olmaya başlar. Beton bina yüzeylerinin iklimsel etkileri ve yeşil alanların azalması sonucu kentsel ekoloji olumsuz etkilenmektedir. Oluşan bu sorunları, sürdürülebilir ve doğal bir şekilde azaltmak için yeni yeşil mimari kavramları geliştirilmektedir.

Çatı ve dikey yeşillendirme sistemleri, bitki örtüsünün bir bina, cephe veya iç duvar üzerine yayılmasına izin veren yapılar olarak tanımlanabilir. İklimsel değişikliğin gündemdeki etkisini arttırmasıyla, yeşil çatı ve dikey bahçelerin kent yaşamındaki yeri de gün geçtikçe önem kazanmaktadır. Kentlerdeki yapıların bu bitkilendirilmiş donatılar sayesinde, artık hissedilebilir düzeylere ulaşan iklim problemine bir çözüm getireceği düşünülmektedir.

Büyük şehirlerde binalarda atıl durumdaki mekanların değişik fonksiyonlarla kullanılması, teras yada çatıların çok amaçlı kullanımı yaklaşımıyla çatıların yeşil alan olarak büyük bir potansiyel teşkil ettiği ortaya çıkmıştır. Çatı ve teras bahçeleri günümüzde kent insanına çok yakınlarında ulasabilecekleri yeşil bir alan sağlamanın yanı sıra insanları dış çevrenin olumsuz koşullarından da koruyabilen birer mekan olarak önem kazanmıştır.

Yeni veya onarılmış binaları da içeren şehirlerde çatı bahçeleri, cephe ve duvar bahçeleri artan yeşil altyapıda gözalıcı dizayn teknikleridir. Onlar yeşil altyapının eksik

olduğu yoğun kent merkezlerinde oluşan birçok zararlı etkinin ortadan kaldırılmasını sağlar.

Benzer birçok şehir gibi Irak Kürdistan Bölgesi'nin (IKR) başkenti olan Erbil de büyüyen kentleşme sorunu ile yüzleşmektedir. Doğanın, kentsel çevre ile bütünleştirilmesi amacıyla, ekolojik peyzaj mimarlığının oldukça basit ve estetik bir yaklaşımla geliştirdiği, kentleşmenin etkilerini azaltan ve ekosistem hizmetlerinin sürdürülebilirliğini sağlayan alternatiflerden sadece biri olan "dikey bahçe" tasarımı, maalesef şu ana kadar bölgede uygulanmış değildir. Bu çalışma bölgede çatı bahçesi, cephe ve duvar bahçelerinin dizayn ve yapımında bir yönlendirme sunacaktır.

Bu çalışmanın amacı, çatı ve dikey yeşillendirme sistemlerinin geniş bir tanımını yapmak, bu yeşil altyapıların özel faydalarını kapsamlı bir şekilde incelemek, dünyada var olan mevcut uygulamalar üzerinden dikey bahçe sistemlerini değerlendirmek ve Irak Kürdistan Bölgesi'nin (IKR) başkenti olan Erbil şehrinde üç örnek yapıda (Kaymakam Binasi, Machko Çay Salonu, Erbil Tower Otel) ilgili bilgisayar yazılımları yardımıyla çatı ve dikey bahçe simülasyonlarını yapmaktır.

## 2. GİRİŞ

Genel olarak bakıldığında çatı, bir binanın mühendislik açısından daha az ele alınan unsurlarından birisidir fakat optimum hizmet performansı sağlamak açısından bina kabuğu için önemli bir bileşendir. Mühendislikte çatı sistemlerinin amacı; su, kar ve rüzgarın binanın içerisine girmemesini sağlamaktır. Çatılar; kışın ve yazın binanın içerisine ısı akışını kısıtlamaktadır. Gelecekteki yağmur, kar ve rüzgar yüklerine karşı dirençli olması düşünülerek tasarlanmaktadırlar (Lanham, 2007).

Zemin seviyesinde kentler; canlı ve enerjik iken, çatılar harap ve cansız kalmaktadır. Verimsiz olarak görülen çatıların her metrekaresi zeminde bulunamayan yeşil alanı yaratmak için bir fırsattır (Ekşi, 2014). Bu fırsata uygulama olanağı sağlayan yeşil çatı, kısmen ya da tamamen toprak tabakası veya yetişme ortamı ile kaplı, bitkilerin dikili olduğu çatıdır (Waldbaum, 2008). Yeşil çatı terimi, bitki örtüsünün daima yeşil olması anlamına gelmektedir (Hake, 2007). Yeşil çatılar kentsel tasarım için yenilikçi bir yaklaşımı temsil etmektedir. Kentsel çevreyi daha yaşanabilir, verimli ve sürdürülebilir hale getirmek için yaşayan malzemeler kullanılır. Yeşil çatıları tanımlamak için kullanılan diğer yaygın terimler yaşayan çatı, bitkilendirilmiş çatı ve ekolojik çatı'dır (Ekşi, 2014). Yeşil çatı sistemleri çatıda bitki büyümesini destekleyen özel sistemlerdir. Çatı membranına ek olarak bu tür sistemler, birkaç ana bileşenden oluşmaktadır. Bunlar kök tutucu tabaka, drenaj tabakası, filtre tabakası, yetişme ortamı ve bitkilendirmedir. Bileşenler uygun bir ortam koşulu ve bitki gelişimini sağlamak adına birlikte hareket etmektedirler (Liu, 2005).

Tarihteki ilk çatı bahçesi fikri, M.Ö. 2000 yılında kurulan antik Sümer şehirlerinden Ur'un büyük Ziggurat ve mabetlerinde ortaya çıkmıştır (Osmundson, 1999). 18. Yüzyılda ise yeşil çatılar, Kuzey Avrupa'da yaşayan insanların evlerine ısı yalıtımı sağlamak amacıyla çatılarını toprakla kaplamaları ve bu toprağı sabitlemek amacıyla otsu türlerle bitkilendirmeleri ile ortaya çıkmıştır (Getter ve Rowe, 2006).

Yeşil çatıların dünya genelinde ticari olarak yaygınlaşması 1960'lı yıllarda Kuzey Avrupa'da görülmüş ve daha sonra da dünyaya yayılmıştır. 1980'li yıllarda çatı bahçelerinin uygulama prensiplerinin belirlenmesi amacıyla Almanya'da FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.- Peyzaj Araştırma, Geliştirme ve Konstrüksiyon Topluluğu) tarafından geliştirilen esaslar (Ekşi, 2014) çatı bahçelerinde kullanılan yapım tekniklerinin belirlenmesini ve dünyada yaygınlaşmasını sağlamıştır (Obendorfer ve ark, 2007).

Geçmişe dönük bir inceleme yapıldığında, araştırmalarda daha çok estetik amaçlı kullanılan "çatı bahçesi" teriminin yerini, küresel ısınma tartışmalarının ivme kazandığı 2000'li yılların başından itibaren "yeşil çatı" teriminin aldığı görülmektedir. Bunun en önemli nedeni bu sistemlerin belirli bir dönemden sonra sadece estetik öğeler olarak algılanmaktan öte, kent ekolojisine katkı sağlayan bileşenler olarak değerlendirmeye başlanmalarıdır (Ekşi, 2014).

21. yüzyılın en hızlı gelişen toplumsal ve fiziksel süreçlerinden birisi de kentleşmedir. Bu ilerlemenin en olumsuz sonuçlarından birisi de doğal dengenin tahrip olması hatta yavaş yavaş yok olmasıdır. Dünya çapında her geçen gün artan çevresel problemlere çözüm arayışları, çevre dostu uygulamaların geliştirilmesine neden olmuştur. Azalan yeşil alanlar ile artan CO2 miktarına, gittikçe grileşen caddeler ile renksizleşen soğuk modern yapılara, azalan enerji kaynaklarına rağmen artan enerji ihtiyaçlarına çözüm bulabilmek için peyzaj mimarlığı ve mimarlık oldukça basit, estetik

ve çevreci bir yaklaşım ile dikey-canlı bahçeleri geliştirmişlerdir. İnsanların yok ettiği yeşil alanların tekrar kazanılabilmesi amacıyla doğanın yapılara bütünleşik hale getirilmesi, var olan yeşil çatı sistemlerinin artmasına ve dikey-canlı duvarların da tasarımlara katılmasına sebep olmuştur. Yeşil çatılar ile benzer faydalara sahip olan dikey bahçeler de; yağmur ve atık suların kontrolü, ses ve ısı yalıtımı, geri dönüşüm, esnek kullanım, estetik ve sosyal faydalar gibi birçok olumlu özelliğe sahiptir. (Tekin ve Oğuz, 2011)

Nüfus artışı hem kentlerde hem de kentlere yakın bölgelerde birçok çevre sorununa neden olmaktadır. Genişleyen kentlerde yer sıkıntısından dolayı yeşil alanların ortadan kaldırılması bu sorunlara ya doğrudan yol açmakta ya da sorunların etkisini arttırmaktadır. Bu sorunların çoğunun; ileride yağmur suyu akışını, su kalitesini, biyolojik çeşitliliği ve gıda güvenliğini tehlikeye sokacak sıcaklık dalgaları gibi iklim değişiklikleri yaratacağı tahmin edilmektedir (Bass ve Baskaran, 1999). Belirtilen bu kentleşme sorunlarını yaşayan kentlerden biri de Erbil'dir.

Erbil şehri, az sayıda parka sahip olması ve nüfusun artması dolayısıyla, atık su arıtımı, su temini, toprak koruma, hava ve gürültü kirliliği gibi pek çok ekolojik zorlukla karşı karşıya bulunuyor. Bu etkileri azaltmak için yaşayan çatılar ve duvarlar önemli bir rol oynayabilir. Yaşayan çatılar ve duvarlar, biyoçeşitliliği zenginleştirebilir, yağış emilimini azaltarak (yağış emerek) bir binanın termal performansını iyileştirip, enerji maliyetlerini düşürebilir. Isı adası etkisine karşı yardımcı olur, yüksek yoğunluktaki sürdürülebilir kalkınmayı destekleyebilir ve şehir görünümünü iyileştirebilir.

En son istatistiklere göre; Kürdistan bölgesinin başkenti olan Erbil'de, yeşil alanların yüzdesinin yaklaşık % 6.5 olduğunu ve uluslararası standartlara göre kentsel alanların % 30'unun yeşil olması gerektiğini belirtmektedir. Çatılar, toplam kentsel yüzeyin yaklaşık % 20-25'ini ve duvarlar da % 40'ından fazlasını oluşturur. Bu nedenle, onları bitkilendirmek, yapı ve şehir ölçeğinde önemli bir etkiye sahip olabilir.

Dikey bahçe fikrinin öncülüğünü yapan peyzaj mimarı Patrick Blanc uzun yıllar kayalarda bitkilerin nasıl yaşadığını incelemiştir. Bu yapılar sıradan ve monoton olmayı, doğal havası ile kabul etmeyerek, gelenekselleşen gri cephelere farklı alternatifler sunabiliyor. Yeşil duvarlar, yağmur suyunun yönetimi, ısı ve ses yalıtımı, ısı adası etkisinin azaltılması, hava kalitesinin arttırılması gibi birçok olumlu özelliğe sahiptir

(Tekin ve Oğuz, 2011). Mimarinin doğurduğu bu yapıların birçok faydası bulunmaktadır. Bunları şöyle sıralayabiliriz;

- Bina cephelerinde pasif iklimlendirme sağlayarak, binaların iklimlendirmesi için harcanan enerjinin tasarrufunu sağlar (Loh, 2008). Japonya, Hoyano da yapılan bir araştırmada, bitkili ve bitkisiz duvar yüzeyleri üzerinde 10‟C e varan sıcaklık farkları kayıt edilmiştir (Loh, 2008). Yaz aylarında gölgeleme yaparak, enerji tasarrufunu sağlayan bitkilerin, kışın yapraklarını dökerek, bina cephesinin gün ışığından faydalanabilmesini sağlamaktadır. Bina cephelerindeki hava hareketlerinin sebep olduğu ısı kazanç ve kayıplarının da dikey bahçeler sayesinde azaldığı bilinmektedir (Loh, 2008).
- Sıcak iklime sahip coğrafyalarda, binaların tüm yüzeylerinin bitkiler tarafından kaplanmasının binaların iç mekan sıcaklıklarının düşürülerek iklimlendirme için tüketilen enerjiden tasarruf etmenin yanı sıra bina çevresinin hava sıcaklığının da düşürülmesi ve kentsel ısı adası etkisinin azaltılması da mümkündür.
- İç mekanların bitkilendirilmesi, insanların yaptıkları solunum sonucu ürettikleri karbondioksitin dönüşümü açısından önemli bir role sahiptir. Bitkiler yaptıkları fotosentez sonucu bir nevi havayı filtrelemektedir.
- Yeşil çatılardan edinilen tecrübe ile, bitkilendirilmiş çatıların bitkilendirilmemişlere kıyasla daha az sesi iç ortama aktardığı bilinmektedir. Bu nedenden ötürü, bitkilerin gerek yoğun şehir dokusu içerisinde gerekse otoyollarda oluşan seslerin dağıtılması ve emilmesi için estetik bir yol olabilir (Loh, 2008).

Yeşil çatıların birçok faydasına rağmen, bir takım zorlukları da mevcuttur; yüksek kurulum maliyeti, ekstra yapısal yük gereksinimleri ve yüksek açıların olduğu çoğu eğimlerde uygulanabilirliği nedeniyle sınırlıdır (Schumann, 2007).

Bu çalışma ile birlikte;

- Dünyadaki yeşil çatı ve dikey bahçe örnekleri incelendi,
- Uluslararası örnekler incelenerek Erbil şehrinin dikey ve çatı bahçesi potansiyelleri belirlendi,
- Erbil şehrinde uygulama örneği geliştirilip örnek bir alan simüle edildi.

## 3. KAYNAK BİLDİRİŞLERİ

Tezin bu bölümü dört ana başlık altında ele alınmıştır. Bunlar; Giriş, Yeşil Çatılar ve Yeşil Duvarlar, Yeşil Çatıların Uluslararası ve Yerel Deneyimlemeleri, son olarak da Yeşil Çatı ve Dikey Bahçe Örnekleri ele alınmıştır. Tezin bu bölümünde Yeşil Çatı, Yeşil Duvar ve Dikey Bahçelerin genel tanımları incelenerek, tipoloji tabloları oluşturulmuştur. Bu yapıların incelendiği ve ekolojik problemlerinde ele alınmasını sağlayan onbir makale tablolaştırılmıştır. Bazı Avrupa, Asya şehirleri, Kuzey Amerika ve Kanada, Avustralya, Arap ülkeleri, İslam Ülkeleri ve Kuzey Irak' ta ki deneyimlemeler başlıklar halinde incelenmiştir. Son bölümde ise Yeşil Çatı ve Dikey Bahçe örnekleri olan; The Jean Vollum Natural Capital Center, The Fairmont Waterfront Hotel Herb Garden, L'Oasis d'Aboukir – Paris – vertical garden (2013), PAMM Pérez Art Museum – Miami – vertical garden (2013), CaixaForum Madrid – vertical garden (2008) incelenmiştir.

Yeşil çatılar üzerine literatürdeki en güncel çalışmalardan biri tarafından Erbil şehri için yapılan 'Çatılar ve Mimaride Gerçekleştirilmesindeki Zorlukları' dır (Yahya et al., 2015).

Bu çalışmanın önerileri şunlardır;

- Liderler ve Plancılar, bu iki tür yeşil çatı bahçesini teşvik etmek ve desteklemek zorundalar ve Erbil'de uygulanmaları için yasa ve mevzuat hazırlamak zorundadırlar.
- Yeşil çatı bahçesinin çevresel öneminin gittikçe artan bir şekilde farkındalığı, kentteki yeşil alanları arttırmanın etkili yollarından biri olarak görülmelidir.
- Yeşil çatıların sulanması için gerekli enerji tüketimini mümkün olduğunca azaltmak için geri dönüştürülmüş su ve güneş enerjisi yardımıyla sulama için ekonomik ve çevre dostu bir sistem önermek mümkündür.
- Erbil'de ve bölgede genel olarak uzun süren bir çevresel gelişme sağlamak için, Yeşil çatı uygulaması, herhangi bir bina veya şehir ana plan tasarımının birinci aşamasında ve her gelecekte genişlemek üzere düşünülmelidir.
- Yeşil çatı alanını desteklemek için bu alanda daha ileri çalışmalar yapılmalıdır.

Yeşil Çatı Tasarımı Yaklaşımlarının İncelenmesi ile ilgili bir diğer çalışma, Doğu Akdeniz Üniversitesi'nde yapılan, ‘Konut Yapıları örnek Çalışması’dır (Bertug, 2013).

Çizelge 1. Bazı önemli tanımların gruplandırılması

| Terimler Dizgesi | Tanım |
|---|---|
| Yeşil Çatı | Ekili yaşayan çatı (Oberndorfer, 2007; (Henry and Frascaria-Lacoste, 2012). |
| Yaşayan Çatı | Ya kahverengi ya da yeşil bitkilendirme çatı sistemleri (Oberndorfer, 2007; Henry and Frascaria-Lacoste, 2012). |
| İntensif yaşayan/yeşil çatı | Bir çatı bahçesinin amacı, sıradan bir bahçe gibi dinlenme ve estetik sağlamadır. Çatıların bu türü en derin topraklarda olup, düzeli onarım gerektirir ve geniş bitki türlerini barındırır (Oberndorfer, Henry and Frascaria-Lacoste, 2012). |
| Ekstensif yaşayan/yeşil çatı | Çatı üretimi biyoçeşitliliği veya diğer çevresel faydaları destekler ve insanların kullanımına yönelik değildir. İnce bir toprak tabakası içerir ve yapımından sonar düşük onarım ihtiyacı vardır (Oberndorfer, 2007; Henry and Frascaria-Lacoste, 2012). |

Çizelge 2. Yeşil-dikey tipleri

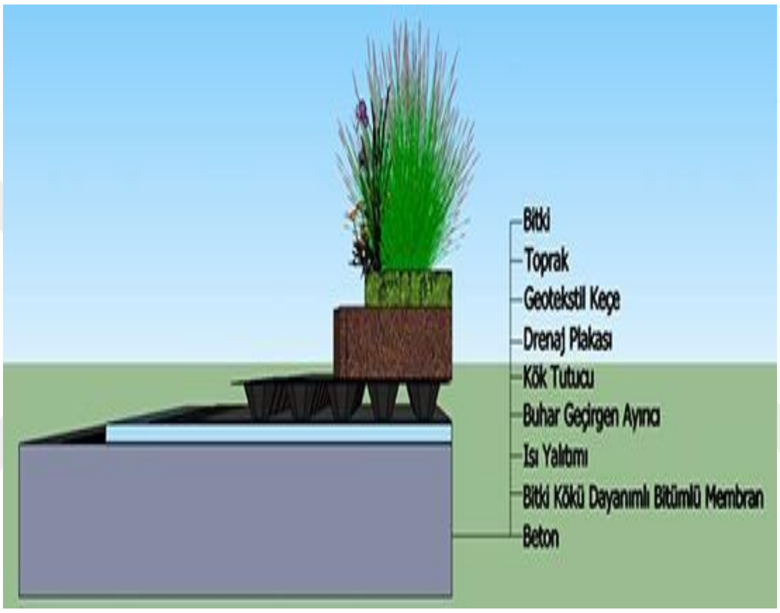
| Terimler Dizgesi | Tanım |
|---|---|
| Yeşil Cephe | Bu tanım, yeşil kapatıcılar ile binaların duvarlarında büyüyen ve ilerleyen tırmanıcı bitkilerden bahseder. Bitki kökleri duvar tabanında bulunur. Bazen bu bitkiler bir tel veya kafes tabanında büyür. (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |
| Yaşayan duvar | Bitki örtüsünü bünyesinde veya yüzeyinde barındıran duvar yapısıdır. Bir yeşil cephe olarak bu yapı, duvar tabanına sabitlenmeye gereksinim duymaz. Birçok yerleşime elverişli duvarlar, modüler system ve kaplı çevrelerden oluşur. Ki bunlar duvar yüzeylerine yerleştirilmiştir fakat su geçirmez membran ve damla sulama sistemlerinin kullanımı ile duvar materyallerinden ayrılır. Bzen bu yapı biyomühendisliğin de konusu olabilir, öyle ki bitki kökleri, duvar sistemlerinin içinde bir amfibiler mekanizma olarak kullanılabilir. (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |
| Canlı duvar | Yaşayan duvar veya yeşil cephe, yapı içine yerleşmiştir. O atmosfer ve iç çevrenin geliştirilmesinde kullanılır. (Henry and Frascaria-Lacoste, 2012; Anonymous, 2015e). |

Çalışma sırasında, yeşil çatıların sınıflandırmasında kullanılan “entansif” ve “ekstansif” terimleri de incelenmiştir. Tercih edilen bitkilendirme tipi, oluşturulacak sistemin altyapı katmanlarının sayısını, özelliğini ve dizilişini etkilemekte, yetişme ortamı derinliğini değiştirmektedir.

Büyük çalılar ve ağaçlar kullanılarak yapılan bitkilendirmeler, yabancı dildeki okunuşlarının farklı telaffuzları ile entansif ya da intensif bitkilendirme tipi olarak tanımlanır.

Yer örtücü, çim, küçük çalılarla yapılan bitkilendirmeler ise ekstansif bitkilendirme tipi olarak tanımlanır.

İki sistemin özellikleri incelendiğinde, ekstensif sistemlerin entansif sistemlere oranla daha basit uygulama özellikleri olduğu görülmektedir. Ancak uygulamadaki basit yaklaşım, bitki ve yetişme ortamı seçimini daha zorlu ve karmaşık hale getirmektedir.




Şekil 1. Çatı bahçeleri katmanları.

Çizelge 3. Ekstensif ve intensif sistem farkları

| Özellikler | Ekstensif | İntensif |
|---|---|---|
| Yapısal (Altyapı) | Basit, hafif, uygulaması kolay katman dizilişi | Yer yer karmaşık, işçilik gerektiren, ek yapısal katmanlar |
| Yetişme ortamı | Sığ, hafif, evaporasyon miktarı yüksek, bitkiler için zor bir ortam | Derin, evaporasyon değeri düşük, ağırlık miktarı yüksek, bitki gelişimi için uygun bir ortam. |
| Bitkisel doku | Yer örtücü ya da otsu, kısa boylu, yetişme ortamı istekleri düşük, dayanıklı, | Yer örtücü, çalı, ağaççık, ağaç, yetişme ortamı istekleri yüksek, |
| Bakım ihtiyaçları | Bakım ihtiyacı düşük, kolay | Bakım ihtiyacı yüksek, gübreleme, sulama, budama faaliyetleri, |


Şekil 2. Ekstensif sistem katmanları.

### 3.1. Yeşil Çatı Tasarımı Yorumları

Yeşil şehirler, yeşil çatı tasarımlarını ve sağlıklı yaşam biçimlerini teşvik etmektedir. Yeşil alanlar, rekreasyon potansiyeli ve cazip bir ortam gibi hizmetler sunmada önemli bir role sahiptir. Yeşil bir kentte, yeşil alanlar ekolojik ve deneysel açıdan çeşitlidir ve işlevseldir. Biyoçeşitlilik kavramı, kent sakinleri için bir dizi rekreasyonel imkânı simgelemek, dahil etmek ve farklı peyzaj şekilleri deneyimleme potansiyelini sağlamak için kentsel bir ortamda genişletilmelidir. Bu süreç, yeşil alanların, boyut, erişim ve sıklık bakımından yeterli olan yerel kültürel ve ekolojik değerlere göre doğru yerlerde bulunmasını gerektirir. Ayrıca sağlıklı bir ekosistemin özelliklerine sahip olmaları gerekir. Konut Yapıları ve Yeşil Çatı, Yeşil Güverte, Yükselmiş Yeşil Yol, Yeşil Topluluk Koridoru, Yeşil Teras, Yatay Yeşil Balkon, Loggia Bağlantılı Podyum çevresel kaygıları karşılar ve iklim değişikliği konularına çeşitli şekillerde de yanıt verir. Yerel iklimin soğutulmasını, suyun ve havanın temizlenmesi ve filtrelenmesini, biyolojik çeşitlilik için yaşam alanlarının ve karbon yutaklarının işlevselliğini sağlarlar. Ayrıca, kentsel ortamda büyük miktarda asfaltlanmamış emici filtreleme yüzeyi sağlayarak, sel kontrolü ve hava temizleme için ara bölgeleri oluştururlar. Duyusal ekolojilerin oluşturulması, doğal alan koşullarının yeşil tasarım sürecine titiz entegrasyonunu gerektirir. Ekolojik sistemler, biyoorganik ve doğal işlemler ve sitenin içinde ve çevresinde gerçekleşen enerji akışları buna dahildir.

Bu süreç, simbiyotik ilişkilerin geliştirilmesi ve kullanıcıların görünüşte bağımsız süreçleri, yapı çevresi ve doğal çevre arasındaki bağlantılar yoluyla yenilikçi ve en iyi performans gösteren tasarım çözümlerini üretir.

Duyusal ekolojileri oluşturmak, bağlamsal alanlarının sosyal, ekonomik ve doğal ekolojilerini geliştiren, hassas ve ilgi çekici yerleşik habitatların geliştirilmesiyle sonuçlanır. Yeşil çatı stratejisi mevcut ortamın kalitesini yükseltmek için tek çözüm değildir, ancak yeni projelerin uygulanması için kârlı ve uygulanabilir bir çözüm olarak önerilir. Tasarımcılar, binalarımızı ve iç koşulları sağlamlaştırmaya başlamadan önce mimariyi, hava, su, toprak ve iklimi çevreleyen çevre oluşturacak şekilde yapılandırma konusunda daha geniş bir sorumluluğa sahiptirler.

Çevresel faydalar, esasen hava kalitesinin iyileştirilmesi, iklimin hafifletilmesi ve fırtına akışının azaltılması üzerine kuruludur ve kentsel alanlarda yeşil alanları artırmak için çok çeşitli fırsatlar sunmaktadır. Aynı zamanda ısı adası efekti için rekreasyon fırsatları yaratan ve çatının yaşam kalitesini artıracak bir yoldur. Bir çatı tasarımının yeşillendirilmesinde asıl endişe ve baskın olan husus, çevreyi ve sürdürülebilirliği etkin bir şekilde entegre edebilmektir. Bu süreç, çevresel entegrasyonun hedeflerini gerçekleştirmeyle ilgili tüm faydalara odaklanmamızı sağlar.

Yeşil cephe endüstrisi gelişmeye devam ediyor ve on yıldan fazla bir süredir gelişen önemli bir proje sayısı var, bu da uzun menzilli yatırım getirisini gösteriyor. Kurulum teknikleri ve inşaat uyumu geliştirilmeye devam ediliyor olup, tasarımcılar yeşil cepheyi yapılara dahil etme kabiliyetini zorlamaya devam ederken, yenilikçi tasarım uygulamalarını da ileriye götürmeye çalışmaktadırlar. Bu süreç, açıklanan hususları dikkate alarak güçlendirilebilir. Bu özetlenen sürecin tamamlanması, standart yapı unsuru olarak yeşil cephelerin genel kabul görmesini sağlamaya yardımcı olacaktır.

## 4. MATERYAL VE YÖNTEM

Yoğun nüfuslu kentsel yerleşimlerde görülen çevre sorunlarını azaltmak ve sürdürülebilir gelişmeyi teşvik etmek üzere dünya genelinde hükümetler ve sivil toplum örgütleri; yasalar çıkarmak, standartlar belirlemek ve teşviklere kaynak yaratmak için çalışmaktadırlar (Grant, 2003). Birçok kent, binalar daha da yükseldikçe çatı bahçeleri eklemek için dikey boyutta kentsel yeşillendirmeyi genişleterek doğayla bağlarını devam ettirmeyi amaçlamaktadır. Özellikle Avrupa ve Asya'daki çoğu kent, binaların çatılarını yeşillendirmeye başlamıştır (Yuen ve Hien, 2005).

Bu çalışmanın amacı çevre sorunlarının etkisini azaltmak için alternatif bir çözüm olarak çatı bahçelerini ve dikey bahçeleri sunmaktır. Dikey bahçelerin kentsel ölçekteki önemi ve artan kullanım olanaklarıyla dikkat çekmesi sebebiyle bu çalışmada çatı bahçeleri, dikey bahçe tasarımı konusu ele alınmıştır.

Çatı bahçeleri pasif ve doğa dostu teknolojiyi yeni veya mevcut bir gelişime dâhil etmenin güzel bir örneğidir. Çatı bahçeleri kentlerin çevre üzerindeki olumsuz etkilerinin hafifletilmesine yardımcı olur (Liu, 2002).

En erken bilinen çatı bahçeciliği ipuçlarının M.Ö. 2500 yıllarına kadar uzandığı düşünülmektedir (Cunningham, 2001). İnsan yapımı bahçelere dair bilinen ilk tarihsel referanslar, eski Mezopotamya'da (Irak ile Mısır arasında yer alan medeniyet) yer alan zigurat'lardır (Şekil 1). Zigurat'lar taştan yapılan büyük basamaklı piramit kulelerdir, tapınak görevi üstlenmektedir ve aşamalar halinde inşa edilmiştir (Osmundson, 1999). Çatılarında ise bitkilendirme tabakası bulunmaktadır (Cunningham, 2001).

Bu tezin çalışma alanı, Irak'ın kuzeydoğusunda yer alan ve Irak Kürdistan Bölgesi'nin başkenti olan Erbil şehri (36 ° 11'28 "N 44 ° 0'33" E) 'dir (Şekil 4). Erbil, dünyadaki en eski yerleşim yerlerinden biridir ve M.Ö. 6000 yılına dayanan tarihi bir kent yaşamına sahiptir (UNESCO, 2010). Kentin yüzölçümü 130 $KM^2$ 'dir. Ekim 2008 itibariyle Erbil şehrinin nüfusu 1.025.000 olup, Irak'taki en büyük şehirlerden biri haline gelmiştir (KRG, 2012). Erbil nispeten düz bir alanda bulunur ve deniz seviyesinden 426 metre yüksekliktedir.

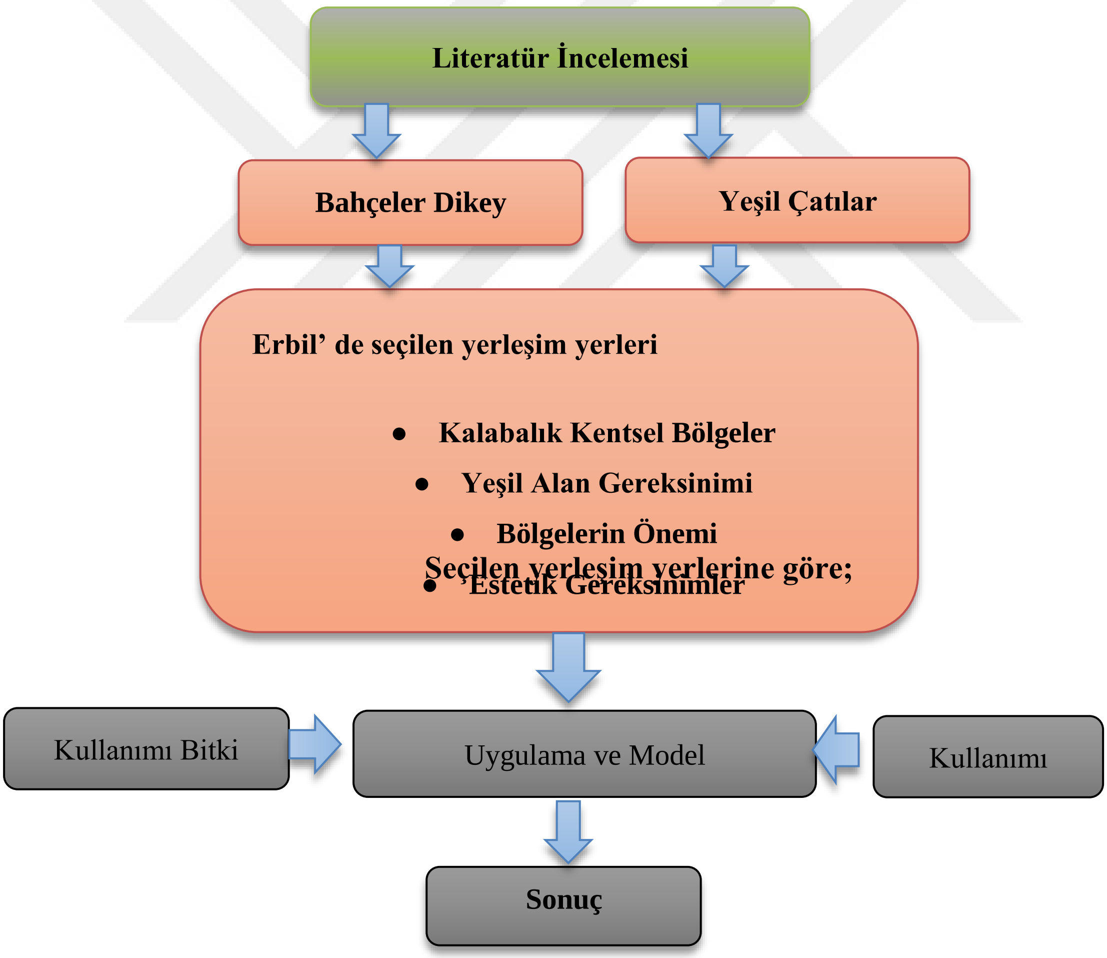
Bu çalışma ile birlikte Erbil şehrinin dikey bahçe dizaynı için önemli unsurlar olan; iklim, rüzgar, yağış faktörleri de incelenmiştir.

Bu çalışmada, Erbil şehrinde bulunan üç yerleşim yeri dikey bahçe dizaynı açısından incelenmiştir. Bunlar; The Mayor Office Building**,** Machko Tea Shop, Erbil Tower Hotel'dir. Bu çalışma sürecinde faydalanılan bilgisayar yazılımları ise; AutoCAD 2014, 3DMax 2015 ve Lumion 6 olmuştur. Yüksek nüfus yoğunluğuna sahip bölgelerde yeşil alanları oluşturmaya katkıda bulunan bir alanı yaratmada mimarinin problemi yeşil alanların eksikliği ve açık alanlarda binaların hakim olmasıdır.

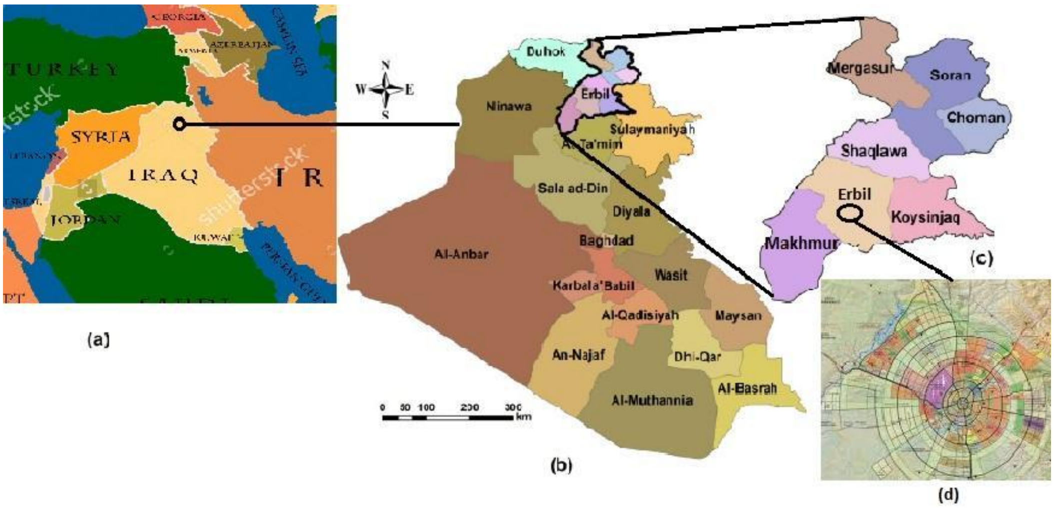
Irak Kürdistan Bölgesi (IKR)'nin başkenti olan Erbil şehrinde yeşil alanların oranı %7' den az olup, ki bu da uluslararası oranın %30 olması gerekliliği nedeniyle tehlikelidir. Henüz Irak Kürdistan Bölgesi (IKR)'nde yeşil altyapının bu dizaynının nasıl yapılacağı hakkında yeterli veri yoktur.

Yapılan araştırmalar neticesinde yeşil çatıların yapım sürecindeki aşamalar incelenmiş olup, yurt dışından yeşil çatı örneklerine yer verilerek bu örneklerin yapım süreci kapsamında irdelenmesi ve belirlenen kriterler dahilinde karşılaştırılması yapılmaktadır. Konu ile ilgili olarak gerek yurt içinde gerekse yurt dışındaki literatür taranmış; çeşitli kişi ve kuruluşlarca düzenlenmiş olan seminer, sempozyum, bildiri, panel, konferans notları ve yeşil çatı sektöründeki firmaların uygulamaları incelenmiştir.

Aşağıda bu çalışmanın yöntem diyagramı sunulmuştur;




Şekil 3. Yöntem özet diyagramı.




Şekil 4. Çalışma alanının haritası.

## 5. BULGULAR VE TARTIŞMA

Bu çalışma ile birlikte Erbil Şehri’nde üç yerleşim yeri örnek alan olarak seçilip, dikey bahçe ve çatı bahçelerinin uygulanabilirliği simüle edilmiştir.

Aşağıda sırasıyla bu üç yerleşim yeri için simüle edilen projelerden elde edilen verileri inceleyelim;

### 5.1. Kaymakam Binasi

Bu yapı resmi bir bina olup, proje de yapının çatısı yoğun yeşil çatı olarak dizayn edildi. Çatı da iki iç bahçe dizayn edilerek çimlendirilmiştir ve bu iki avlu arasında engel mevcut değildir. Bu iki iç bahçe devlet memurları ve normal insanlar arasındaki ilişkiyi yansıtmaktadır. Erbil şehri sıcak havaya sahip olduğu için gölgelik alanlara ihtiyaç vardır. Bu nedenle de gölgelik alanda su çeşmesi kullanıldı. Çatının patika yürüme yollarında ahşap ve taş gibi doğal malzemeler kullanılarak konseptte organik bir form oluşturuldu. Projede kullanılan bitki ve çiçeklerin seçimi aşğıda verilen kriterlere göre belirlendi;

- Erbil’in hava ve konumuna uygunluğu,
- Suya dayanıklılığı
- Gölge gereksinimi ve estetik

Projedeki tüm ağaçlar saksılardadır çünkü ağaçlar çok toprağa gereksinim duyarlar ve rüzgara karşı mukavemetleri vardır. *Tilia Cordata,* oturma alanlarında gölgelik olarak kullanılmıştır. *Vitis vinifer* ise kamelyalarda yine gölgelik olarak kullanılmştır. Ayrıca bu dizaynda *Citrus* bitkisi de kullanılmış olup, bu bitki erbil çevresi için oldukça uygundur. Pembe çiçekli *Lagerstroemia indica* da bu çatı da kullanılarak etkileyici bir görüntü elde edilmiştir. *Araucaria excelsa* çamı ve beyaz çakıllar kullanılarak da çatı bahçesinde etkileyici görünü oluşturulmuştur. *Citrus* çevresine çember şeklinde mavi renkli *Hydrangea* çiçeği kullanılarak, ağaç ve çiçekler arasındaki denge sağlanmıştır. *Melissa* çiçeği etrafında. *plumbago capensis* ve *abelia* çiçekleri kullanılmıştır. *Bamboo* ve *Euonymus japonicus Var* bitkileri ise duvar boyunca dümdüz yetişebildiği için buralarda kullanıldı.

Çizelge 4. Bitkiler

| Bitki Adı | Renk |
|---|---|
| *Robinia pseudoacacia pictum* | |
| *Vitis vinifera* | |
| *Plumbago capensis* | Blue |
| *Hydrangea* | |
| *Citrus* | |
| *Bamboo* | |
| *Anthemis* | White |
| *Anthemis* | Yellow |
| *Lagerstroemia indica* | Pink |
| *Melissa flower* | |
| *Abelia flower* | White |
| *Ficus benjamina* | Yellow |
| *Euonymus japonicus var* | |
| *Araucaria excels* | Blue |
| *Agapanthus* | |
| *Hibiscus rosa sinensis* | Red |
| *Hedera helix* | |
| *Buxus* | |
| *Cycas* | |
| *Festuca glauca* | Blue |

*Anthemis* çiçeği, sarı ve pembe olmak üzere farklı renklerde ekildi. *Ficus benjamina* iki eksende de ekildi. Kırmızı renkli *Agapanthus* ve *Hibiscus Rosa Sinensis* ana eksen etrafına ekildi. *Hedera Helix*, duvarı kaplayan girişin yanına ekildi. Ayrıca kullanılan *Cycas* bitkisi resmi binalarda gücü ifade etmede kullanılır.

### 5.2. Machko Çay Salonu

Bu proje de bina çatısı yoğun yeşil çatı olarak dizayn edildi. Çatı tek seviyeli olmayıp farklı kademelere sahiptir. Tüm yürüme yollarında ve üç renkli oturma alanlarında materyal olarak ahşap kullanıldı. Ahşap hafif ağırlığa sahip olduğu için bina inşaasında kullanımı etkili değildir. Bu projede ağaç ve çeşmeler ile gölgelikli oturma alanları dizayn edildi. Bu projedeki temsili dairevi alan Erbil şehrinin şeklini yansıtır. Ki bu şekil şehir merkezinin ortasındak ikale ve etrafındaki bölgelerin temsilidir. Oturma alanları Shar parkını görecek şekilde düşük seviyede dizayn edilmiştir. İki resim alanı dizayn edildi, birincisi ağaçlarla gölgelendirilen oturma alanına ve ikincisi de I ❤ ERBIL ile sağlandı. Çim bloklar ile Kürt Bölgesel Hükümeti bayrağı dizayn edildi ve I ❤ ERBIL yazılarak uzaktaki insanları etkileyebilecek güzel bir görüntü elde edildi.

Çizelge 5. Bitkiler

| Bitki Adı | Renk |
|---|---|
| *Prunus Cerasifera Pissardii Nigra pictum* | Red |
| *Cupressus Arizonica* | Blue |
| *Buxus sempervirens* | Purple |
| *Robinia pseudoacacia* | |
| *Juniperus horizontalis* | Blue |
| *Hedera helix* | |
| *Opuntia ficus-indica* | |
| *Trichocereus pachanoi* | |
| *Echinocactus grusonii* | |
| *Gymnocalycium* | |
| *Lavandula* | Purple |
| *Euryops* | Yellow |

Bu proje içinde kullanılan bitkileri kısaca inecelersek; *Prunus Cerasifera Pissardii Nigra* bitkisi, binanın dış duvarı boyunca kullanıldı. Erbil şehrine uygun olan bu bitki kalenin renkleri ile de denge içindedir. Ayrıca projeye insanların ilgilerini cezbetmede de rol oynar. Cupressus *Arizonica* isimli yeşil çatılara uyumlu bitki de kullanıldı. *Juniperus horizontalis*, I ❤ ERBIL yazılı alanda eğimli bölgelere ekildi. Bu bitki toprağı yatay olarak kapatarak, toprak erezyonunu önlüyor. *Robinia pseudoacacia*, dairevi alana ekildi ve iyi gölge sağlama özelliğine sahiptir. *Hedera helix*, machko's kafenin balkonunun ahşap kamelyasına ekildi.

Alçak çatılarda, *Opuntia ficus-indica* ve *Trichocereus pachanoi* gibi kurak havalarda yaşayabilen bitkiler kullanıldı. *Euryops* çiçeği, çim blokların içinde Kürt bayrağının güneş sembolünü oluşturmak için ekildi.

### 5.3. Erbil Tower Otel

Yeşil cephe ve yeşil duvarlar kulelerde de dizayn edildi. Dizayn konsepti, Irak bölgesi veya Mezopotamya topraklarında yaşamış ve yaşayan farklı millet ve uygarlıklardan gelen farklı tabakalardan oluşur.

Çizelge 6. Bitkiler

| Bitki Adı | Renk |
|---|---|
| *Codiaeum variegatum pictum* | |
| *Epipremnum sp* | |
| *Nemorosa* | Purple |
| *Pteris cretica* | |
| *Begonia* | Blue |
| *parthenocissus quinquefolia* | |
| *Parthenocissus tricuspidata* | |
| *Toxicodendron radicans* | |
| *Campsis Radicans* | |
| *Lonicera japonica* | |
| *Hedera hilex* | |
| *Hedera helix elegantissima* | |
| *Hedera helix variegate* | |

Binaların güney ve kuzey cepheleri penceresiz olup beton yüzeylerdir. Yeşil cephe ve yeşil duvarın dizayn edlebileceği bu yapı, Erbil'de ki önemli yüksekliğe sahip binalardan biri olduğu için, Erbil'de ki herhangi bir yerden görülebilir. Bu proje, yeşil yüzeyler ile binaların büyük kısımlarını kaplayarak güneş ve ısıdan korunmasını sağlar ve ayrıca şehire estetik ve hoş bir görüntü sağlar.

Bu proje içinde kullanılan bitkileri kısaca incelersek; *Codiaeum variegatum pictum', Epipremnum sp, nemorosa' (*purple), *Pteris cretica'* ve *Begonia'* (mavi) bitkileri bu simülasyonda balkonlarda kullanıldı. *Parthenocissus quinquefolia, Parthenocissus tricuspidata, Toxicodendron radicans, Campsis Radicans, lonicera japonica, Hedera hilex, hedera helix elegantissima* ve *hedera helix variegate* bitkileri ise farklı tabakalı yeşil cephelerde kullanıldı.

## 6. SONUÇ

Kontrolsüz nüfus artışı, yaşanan göçler, sanayileşme ve paralelinde gelişen çevre kirliliği ve doğal kaynakların tüketimi günümüzde karşımıza çıkan kentsel sorunlardır. Bu sorunlar karşısında; geçmişten beri var olan ancak günümüz koşulları ile geliştirilen çevreci çözümlerden biri de çatı bahçeleri ve duvar bahçeleridir. Çatı bahçeleri sahip oldukları ekolojik ve rekreatif işlevleri ile şehirlerde doğal bir yaşam alanı oluşturmada ve şehir içinde kişi başına düşen yeşil alan miktarının arttırılmasında önemli rol oynar. Peyzaj mimarlığı disiplini de bu teknolojinin tasarım sürecinde önemli rol oynamaktadır. Çatı bahçeleri ve duvar bahçeleri yapı sahibine genelde kullanılmayan çatı alanlarını, enerji verimliliği, yağmur suyu yönetimi, ses yalıtımı ve estetik geliştirmeler için kullanma fırsatı sunar.

Sonuç olarak, çatı bahçeleri tüm yararlarına rağmen, Erbil'in kentsel planlamasında kullanılmamaktadır. Erbil şehri yoğun nüfusu nedeniyle birçok çevre sorunuyla karşılaştığından, çatı bahçeleri ve duvar bahçeleri kentleşme sürecine uygulanmalıdır. Yerel yönetimler yeşil çatılara daha fazla önem vermeli ve bina sahiplerini geleneksel çatılarını canlı çatılara dönüştürmek için teşvik etmelidir.

Bu şekilde, Erbil halkının yaşadığı yaz aylarındaki kentsel ada ısısı etkisi, kış mevsimindeki yüksek hava kirliliği, yoğun ve plansız kentsel planlamadan kaynaklanan görüntü kirliliği gibi sorunların çoğu azaltılabilir ve böylece kent hem estetik hem de ekolojik olarak iyileştirilebilir.

**CIRRICULUM VITAE**

Darbaz Pirot MANKURI was born in Erbil North of Iraq in 1991. He completed primary and secondary school in Qaladze City and undergraduate study in Architecture Department, Faculty of Engineering, at University of Cihan in 2014. He was registered to Master of Science program in Landscape Architecture Department, Van Yüzüncü Yıl University, Van-Turkey in 2015.