SUSTAINABLE LANDSCAPE DESIGNS: INTRODUCTION TO GREEN ROOF ECOSYSTEMS AND THEIR ADAPTATION TO THE SEMI-ARID CLIMATE OF CYPRUS

A THESIS SUBMITTED TO THE GRADUATE

SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

By
SİNEM YILDIRIM

In Partial Fulfilment of the Requirements for
the Degree of Master of Science
in
Landscape Architecture

NICOSIA, 2017

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not orginal to this work.

Name, Last name: Sinem YILDIRIM

Signature:

Date:

To my family and to my advisor…

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ABSTRACT

Green roofs are important green spaces for the vegetation of urban landscapes. Green roof systems can enhance rainwater management, cooling and isolation of buildings, mitigation of urban heat island, and also can help ecosystem functioning in order to contribute to a sustainable urban environment. Green roofs can also facilitate wildlife population movements and may serve as refuges for rare species. Population in urban areas is constantly increasing and it is estimated that until 2030, the population will increase by 61%. In this research, literature review has been carried out on green roof systems and their benefits. Also a feasibility analysis of possible green roof application in semi-arid climate conditions of Cyprus was performed. Additionally telephone interviews were carried out with several construction companies in north Cyprus with the aim to determine interest of the companies on green roof systems in Cyprus. Research results shown that the establishment of extensive green roof system in semi-arid climate of Cyprus, together with roof layers and vegetation would cost approximately 232 TL per square meter. When we consider the insulation benefits on buildings and positive storm water management effect of green roof systems this cost is negligible. On the other hand, interviews with construction companies shown that there is a little interest to use green roof systems. However this may be because of lack of knowledge on their benefits. Therefore, this research emphasizes that green roof systems can be easily implemented in Cyprus with the support of local authorities.

Keywords: Sustainable design; green roof systems; cost analysis; adaptation; Mediterranean climate

ÖZET

Yeşil çatılar, kentsel peyzajların bitki örtüsü için önemli yeşil alanlardır. Yeşil çatı sistemleri, yağmur suyu yönetimini, binaların soğutulmasını ve izolasyonunu, kentsel ısı adası etkisinin azaltılmasını sağlayarak ve ayrıca sürdürülebilir kentsel çevreye katkıda bulunarak ekosistemin işleyişine yardımcı olabilir. Yeşil çatılar ayrıca doğal yaşam hareketliliğini de kolaylaştırabilir ve nadir türler için sığınak görevi görebilir. Kentsel alanlardaki nüfus sürekli olarak artmaktadır ve 2030 yılına kadar nüfus % 61 seviyesine ulaşacağı tahmin edilmektedir. Bu çerçevede bu araştırmada, yeşil çatı sistemleri ve faydaları üzerine literatür taraması yapılmıştır. Ayrıca, Kıbrıs'ın yarı kurak iklim koşullarında muhtemel yeşil çatı uygulamasının fizibilite analizi yapılmıştır. Buna ek olarak, şirketlerin yeşil çatı sistemleri hakkındaki ilgisini belirlemek amacıyla Kuzey Kıbrıs'taki birkaç inşaat firmasıyla telefon görüşmesi gerçekleştirildi. Araştırma sonuçları, Kıbrıs'ın yarı kurak ikliminde çatı katmanları ve bitki örtüsü ile birlikte geniş yeşil çatı sisteminin kurulmasının metrekare başına yaklaşık 232 TL'ye mal olacağını göstermiştir. Binalar üzerindeki izolasyon yararlarını ve yeşil çatı sistemlerinin yağmursuyu yönetimine olan olumlu etkisini göz önüne aldığımızda bu maliyet önemsizdir. Oysa ki, inşaat şirketleri ile yapılan röportajlar, yeşil çatı sistemlerinin kullanımına ilginin az olduğunu gösterdi. Yeteri kadar bilgiye sahip olmamalarının bu duruma sebebiyet vermesi söz konusu olabilir. Sonuç olarak bu araştırma, yerel yönetimlerin desteğiyle, yeşil çatı sistemlerinin Kıbrıs'ta uygulanabileceğini vurgulamaktadır.

Anahtar Kelimeler: Sürdürülebilir tasarım; yeşil çatı sistemleri; maliyet analizi; adaptasyon; Akdeniz iklimi

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CHAPTER 1

INTRODUCTION

1.1 Overview of Green Roof Systems

The world's population is increasingly shifting from a rural lifestyle to inhabiting urban areas. Globally urbanized areas are the most rapidly expanding habitat type (Faeth et al., 2011). New attitudes are required to address the complex concerns related to increasing world population, resource reduction and a rapidly decreasing quality of human habitat. The sustainability issue has begun as one of the leading concerns from these global issues. Sustainability as a global term firstly used in 1890 within IUCN's World Conservation Strategy. The FAO's definition states that sustainability is the handing and conservation of natural resources and the orientation of technological and institutional change so as to safeguard the continuous fulfillment of human needs for present and future generation. A major problem with increased urbanization is the escalation in area of impermeable manmade structures and coverings. This has led to a number of infrastructural and environmental issues within many towns and cities (Berndtsson, 2010).

Roof gardens have ancient roots with the original documentation examples of the hanging gardens of Semiramis in Syria. Present-day decorative roof-garden projects are a modern day correspondent designs for high-profile international hotels, business centers, and private homes. Such green roofs, with their deep soil profiles and diverse plantings are referred to as "intensive" green roofs, giving the appearance of conventional ground-level gardens (Oberndorfer et al., 2007). "Green roofs" or "vegetated coverings" are not only important for their aesthetic values they are also important because of their energy reduction capabilities (Peri et al., 2012).

While green roofs have a relatively long history, their numbers have increased considerably during recent times. The number of green roof systems in North America has been increased by 35% during 2008. Whilst these constructed ecosystems provide numerous services, the reduction of heat fluctuation into buildings and storm water detention and retention are the most widely studied subjects. A larger scale deployment of green roofs is also anticipated to aid the reduction of the urban heat island effect (Lundholm et al., 2010). Much of the early research into green roof systems took place in northern Europe (Germany, Switzerland, and Scandinavia) (Dvorak and Volder., 2010). Within Europe, the greatest use of green roof technology has been seen in Germany; in 2008 this industry was purportedly worth $77 million. This amounted to 13.5 km^2 of green roofs, equating to 14% of all flat roofs. Eighty percent are ‘extensive systems’, providing the most cost effective solution when compared to ‘intensive roof systems (Castleton et al., 2010). Such systems reduce the energy requirements for interior climate control. Green roofs not only capture and disperse solar radiation; they can also alleviate storm-water runoff from building through the collection and holding of rainfall. This in turn reduces the volume of water flow into storm-water infrastructure and urban waterways. Other beneficial effects consist of wildlife habitats, increased biodiversity, improved air-quality, and reduced urban heat-island effect (Oberndorfer et al., 2007).

As urban green area become ever scarcer, a drop evapotranspiration levels occurs, which in turn leads to a reduction in rainfall levels further reducing evapotranspiration (Mechelen et al., 2015). To date there has a copious amount of research with regards to using plants for anti-pollution measures. However, most of this work has not been related to green roof systems. Vegetation has a number of ways in which it can remove pollutants. For example, gaseous pollutants can be removed via the stomata, particulate matter can be intercepted via their leaves and stalk, and some are capable of breaking down poly-aromatic hydrocarbons in plant tissues or soil (Rowe, 2011). A lack of green areas can result in a decrease in canopy interception and transpiration, which can lead to elevated temperatures and decreased humidity (Berndtsson, 2010).

European green roofs can be ecologically rich comprehending high levels of insects, birds and wildlife. Findings include visitation and dwelling of butterflies, birds, and invertebrates, together with endangered plant species. For example in Zurich, Switzerland, one of the world's oldest green roofs contained 170 plant species which included 9 native rare or endangered orchid species (Dvorak and Volder, 2010).

Living roofs not only provide aesthetic and psychological benefits for people. They have positive impact on human health too. Green roofs are supporting urban agriculture, helping to reduce sound pollution through sound wave absorption (Dunnet and Kingsbury, 2008; Oberndorfer et al., 2007). Green roof systems are defined as a complex for growing plants that includes a variety of specific materials with particular functions. The components are layered as follows: water-proofing, drainage material, filter, growing medium, vegetation and edge protection (Boivin et al., 2001) (Figure 1.1).

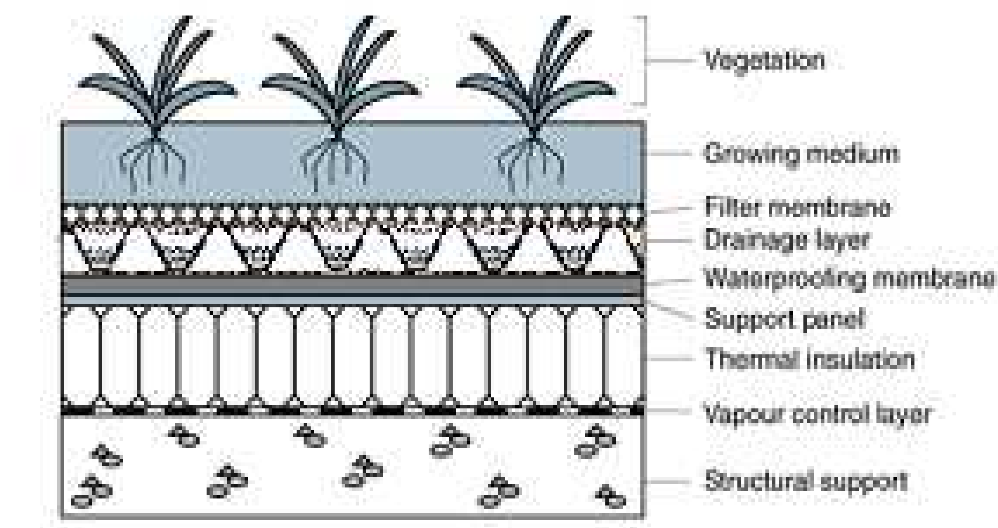

Figure 1.1: A schematic section of a green roof system (Berndtsson, 2010)

There two types of green roof system, extensive and intensive. Extensive green roof systems have between 50 and 150 mm of growth medium. This restricts the size of plants which can be used and minimizing the weight stresses of the green roof on the building structure. Often this type of green roof is a later addition to remaining buildings; this does not require any alteration or strengthening of the existing roof's structure. Intensive green roofs have a much greater depth (10 to 1200 mm) of growing medium, and enable the planting of much larger plants. Large bushes and even small trees can be planted on intensive green roofs. Additionally "roof top gardens" can endure foot traffic and enhance the aesthetic value of the building. These types of green roof systems place heavy load pressures and therefore require specialized engineering support solutions (Kosareo and Ries, 2007).

Living roofs are progressively more valued for the advantages they offer in urban environments. It is well known that they provide several benefits which include: reducing heating and cooling requirements of buildings, mitigating urban-heat islands by cooling roofed surfaces, providing aesthetic value, storing rain water which reduces runoff and flooding, improving air quality by sequestering pollutants, cooling photovoltaic panels and potentially improving their electricity production, and proving habitat for native organisms (Blaustein et al., 2016).

Green roofs provide passive cooling preventing solar radiation permeating to the rooms below. During the past decade numerous studies have been performed in order to evaluate the potential benefits of green roof system. Such studies determined that green roof systems can provide benefits both in winter (reduced heating) and summer (cooling) (Castleton et al., 2010).

One study compared the heat gain of two different roof systems in Toronto (Canada) by Castleton (2010), both had 75-100 mm of lightweight growing medium. His research results showed that heat gain for the green roof was between 70-90% less in summer and heat loss in winter was reduced by 10-30%. On the other hand it is known that urban water-resistant hard surfaces also intensify storm water runoff and lead to higher levels of erosion (Lundholm et al., 2010). Studies in Germany showed that intensive green roofs could reduce annual runoff between 65-85% and extensive roof systems provided similar results (27-81% reduction) (Berndtsson, 2010).

Results from the US (Chicago, Philadelphia and Portland) shown that an average rainwater retention can be around 75% with extensive green-roofs (Scholz-Barth, 2001). Variation in reported results is mainly effected by media depths and vegetation types (Villarreal and Bengtsson, 2005).

Future ideas on the directions for research may include areas such as planting types, improved growth media, rooftop horticulture, water quality, water runoff, irrigation systems, using grey water, pollution reduction , carbon repossession, health benefits, etc. (Rowe, 2011)

1.2 Green Roofs in Europe

Green roof research and product development in Europe has been in existence for almost half a century. A green roof is a vegetated roof or deck designed to provide urban greening for buildings, people, or the environment and became popular across Europe over the last few years. Europe's broad experiences with the technology eventually led to guidelines and standards that were supported by university led research, field observations, and product or component development. Probably the most widely used set of guidelines for green roofs throughout Europe is the FLL Guidelines (FLL refers to the ForschungsgesellschaftLandschaftsentwicklungLandschaftsbau [The German Landscape Development and Design Research Institute] Key criteria of the direction was the possibilities of the transfer of German directives open to discussion and can appropriate in different regions and climate conditions. FFL has been working on standards for green roof technology for 25 years. Regulation all green roof although it does not provide a solution for its problems, the green roofs are Tool. The common point of view is that this German directive does not interfere with American standards, or it does not replace it. But the FFL direction, built around millions of square feet of green roof is a very good resource because it is based on your experience. The document covers the design, construction and maintenance of green roofs.

Global energy consumption contributes to environmental pollution, degradation and greenhouse emissions. There are four sectors which are greatest consumer of energy, these are: industrial, building (residential/commercial), transportation and agriculture. (Dvorak and Volder, 2010). Netherlands, Hungary, Denmark, UK and also had shown great interest in application of green roof systems with international standards. In the European Union (EU), the building sector accounts for>40% of all energy consumption. Sustainability issues are now becoming a higher priority within the construction industry, from both financial and ethical reasons. In Europe, the Energy certification of buildings has motivated improvements in the thermal performance of buildings. With improved building designs and operation procedures, significant energy savings can be achievable. Hence, architects have an important role to play in solving energy usage issues, through the making correct design decisions, suitable material selection and the integration of building into different building components. It is stated that thermal insulation materials are the first step in reducing the energy consumption and maintaining suitable interior temperatures (Pargana et al., 2014).

In Germany, the first widespread use of green roof designs began at the end of the 19th century. A number of low cost industrial worker apartments were constructed, however, this accounted for <1% of all buildings. The green roof system deployed was a simple design consisting of a layer of gravel and sand with the addition of some soil. The reason this system was added to the roofs was as a fire protection method (Köhler, 2006).

Green roofs offer an interesting case for studying perceptions of existing symbolism associated with traditional nature, such as forests or lakes, providing a unique perspective in comparison to traditional terrestrial landscapes (Mesimaki et al., 2017). Castleton et al. (2010) carry out review research on green roofs for building energy saving assessments. In UK, this research has shown that the retrofitting of existing buildings has a great potential (Figure 1.2).

Green roofs globally are used as part of climate change strategies and different policy instruments are used to promote green roof systems (i.e. subsidies). Such instruments require social equity access, therefore policies need to understand the access to services provided by green roofs for various groups, such as low-income families (Mesimaki et al., 2017). After 1980, many green roofs were constructed with the aim of increase urban vegetation. The history of green roof development in Berlin is documented in (Koehler and Keeley, 2005).

Figure 1.2: Retail Sedum Roof, Canary Wharf, London (Kadas, 2006)

In Germany, during the early 1980s, there was a change in urban planning occurred. Apartment buildings from the time of early industrial development were to experience renovation. Citizens preferred living in mature neighborhoods of the town centre rather than the new multistory buildings of the centers. Apartments were combined with existing properties. Additional levels were added to existing buildings, so a typical four-story apartment building received a fifth level with roof windows and terraces. In the early days these new apartments were uncomfortable because of pitiable insulation. However, with the influence of urban ecologists, town planners began to reconsider using new green roof technologies. A new building code was developed where extensive green roofs should be used on apartments in central parts of the city. Additionally, the introduction of incentive programs helped to reduce the additional costs of installation (Köhler, 2006).

1.3 Green Roofs in Mediterranean Region

Even under Mediterranean conditions green roofs significantly alleviate storm water runoff by reducing the amount runoff volume and increase of concentration time. However, poorer performance levels could experience during periods of high precipitation (Fioretti et al., 2010). In detail, a green roof substrate consists of both inert (75-80% mass) and organic fractions (20-25% mass). Elements such as fertilizers should also considered, which also presents additional difficulties (Anderi da Silva and Kulay, 2005; Peri et al., 2012).

Integrated water and energy management is a major step towards achieving environmental sustainability and its associated reduction in carbon emissions. Understanding water and energy fluctuations between buildings and their immediate environment is a contemporary issue regarding sustainability and comfortable living conditions for urban areas. Sustainable construction is one of the recommendations from the European Union Thematic Strategy on the Urban Environment. Sustainable construction can lead to improve energy savings, reducing the day to day use of resources. In this area alternative rooftop coverage solutions can play an important role and greening technologies (green roofs, vegetated roofs, eco-roofs or nature roofs) have become popular.

Green roof applications have been primarily developed in colder, temperate regions where the climatic conditions, particularly rainfall are favorable for vegetation growth and survival. However, international research efforts in other climatic regions are scarce (Fioretti et al., 2010). Research carried out by Istanbul University in Istanbul analyzed a data on the thermal properties of a typical large green roof system. The green roof thermal properties were compared to a bituminous membrane roof (reference roof). This research confirmed that a typical large green roof with medium of 50 mm thickness provided thermal protection against extreme temperatures. The effects of excessive temperature were reduced by 79% using the green roof system. These results show that green roofs are sustainable option for climatic conditions similar to Istanbul, Turkey (Eksi and Uzun, 2013) (Figure 1.3).

Figure 1.3: Zorlu Center in İstanbul photo taken by Yorgancıoğlu (2017)

1.4 Aim of the Study

Due to increasing human population, our cities are rapidly developed as a result of our rapid expansion, largely covered with concrete and asphalt. The green areas that have to be in the city are not able to withstand the intensive pressure of the security functions and the work places, leaving their places to concrete. Air pollution has become a major problem for many cities. The increasing numbers of high buildings obstruct air circulation, causing the air to warm up with pollution. As water use increases in cities and industrial areas, the reduction in the amount of concrete which has led to a greater burden on the city's wastewater systems. Dependent on the inadequate infrastructure, many cities have to struggle with floods. One of the most effective solutions against this situation is to restore the lost plant areas on the structures that destroy them, that is to say, the greening of the roofs. Objectives of green roof application are reducing the risk of drainage and sudden floods by holding down the rain water, reducing the effect of temperature changes on the structure, thereby reducing thermal stress, adding aesthetic value to the structure, adjusting heat and humidity balance, filtering dust and air and water pollution, to create a living area, to insulate in winter, to contribute to thermal insulation by giving coolness in summer, to provide sound insulation by absorbing noises, to reduce heat island effect, to make contribution to air quality by using carbon dioxide in the atmosphere, to give oxygen and to create special resting places with green roofs and in doing so make it possible to increase the economic value and the preference. For this reason, the green roof system is thought to be a useful solution to the environmental problems experienced in Cyprus, which has a Mediterranean climate. The aim of this study is to investigate the factors to be taken into consideration when applying green roofing suitable for Mediterranean climate in Cyprus conditions, to determine the layers to be used and to carry out the feasibility analysis of the possible application. There has been noticeable urbanization in Kyrenia, Nicosia and Famagusta regions in Cyprus.

There are two main types of green roofs; intensive and extensive green roof. In this research we would like to investigate implementation of an extensive green roof system in Nicosia. The purpose of our work is to analyze the cost of the targeted green roof and to optimize the green roof systems for semi-arid climatic conditions in Nicosia. In addition we would like to determine the views of construction companies in Cyprus on green roofing.

1.5 Limitations of the Study

In this research, interviews with construction companies were carried out with telephone interviews, by asking a few questions. However, no interview was made with every construction company with a contact address. In the survey, companies were searched until we receive the essential information. Despite some minor difficulties, the desired result has been achieved.

1.6 Thesis Overview

In many ways there are "icons" for green roofs for sustainability. It has many advantages such as increasing the environmental performance of buildings, clearing the air and increasing biodiversity. Unfortunately, our country is a bit far from sustainable city developments and application of the green roof systems. For this reason, when we investigate the topic we are talking about, the subject comes to the agenda. In order to raise consciousness of public and minimize the damage to nature, it is necessary to discuss sustainable city development issues such as green roof applications. Therefore, the green roof systems and their possible application in Cyprus have been discussed within this thesis. In the first chapter we discussed the sustainability issues which arise from the need for new attitudes because of the increase in world population, the reduction of resources and the decline of the quality of human habitat. The green roof designs which support sustainability of urban areas and its benefits have been widely discussed.

Also green roof examples from Europe and the Mediterranean were explained, the limitations of research, and a general overview of this thesis were explained. Chapter 2 is a literature review of the effect of green roofs on cooling the cities, reducing heat island effect, and supporting biodiversity. In Chapter 3, material and method were discussed. Research questions and objectives on the green roof, the effects of the research, the methodology of the research, for example, the questionnaire, the interviews, the data analysis, and the green roof cost analysis for the Nicosia region have been mentioned. Chapter 4 includes results, while Chapter 5 discusses conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Green Roofs Around the World

The city of New York has a range of emerging human and environmental issues. The implementation of green roofs as a technology has the potential to mitigate a number of environmental and human health problems (Rosenzweig et al., 2006). Such problems are urban heat island effect, global climate change, and storm water runoff. However, spatial research in the area concerned is required to validate such models. Objectives to quantify the environmental functions, financial benefits and application costs. In this report, the primary emphasis was on green roofs which were lightweight, thin (4-6 inches of growing medium), and planted with hardy, drought-resistant plants. All of these parameters were to minimize weight, cost, and maintenance. This type of green roof is generally referred to as 'extensive'. However, green roof designs can support a wide variety of planting styles (grass, flowers, trees, shrubs, and/or crops, etc.). Green roofs deliver a number of environmental benefits, such as natural cooling insulating, soil water-retention and vegetation into the urban landscape. It is clear green roofs have a number of possible benefits; here we will concentrate on several key sectors. These sectors include (1) energy use and global climate change, (2) urban heat island effect, and (3) storm water runoff. Green roofs are an excellent example of urban design, with inclusive elements providing several environmental services (Grant, 2006).

Four recycled materials have been developed into substrates for extensive green roofs. These are crushed red brick (the U.K. industry standard substrate base and therefore used as a control) and three different pellet types formed from: clay and sewage sludge, paper ash and carbonated limestone. Investigations regarding the organic material for plant nutrients and properties such as pH, particulate size, density, XRF and leachate analyses were made. Experiments performed in a greenhouse environment provided important information regarding the interactions between the aggregates and organic material.

This means that the aggregate can have significant effects on the resulting plant growth. Particle and loose bulk density analysis meant all aggregates were classified as lightweight and leachate analysis were all within the legal limits. All aggregates are available commercially and are competitively priced with crushed red brick. Therefore, it is suggested that these alternative substrates provide a suitable alternative both from an economic and environmental stand point (Molineux et al., 2009). Green roofs have become popular alternatives in dealing with a number of urban environmental problems. Most studies have focused on extensive green roofs, this has led to a paucity of information for complex intensive roofs. Another study examined the seasonal effect on the performance and efficiency an intensive green roof. Woodland was placed on a Hong Kong rooftop; sensors were used monitor climatic and soil parameters. This site had 100 cm soil depth however, a thin soil layer (10 cm) was enough to restrict to the penetration of heat into the building. The seasonal effects were reduced solar radiation passing the tree canopy, but trapped air had an insulating effect increasing air temperature below the canopy. However, in winter, there is notable heat loss increasing energy consumption. This is contrary to finding at temperate latitude. Optimization of intensive green roof design in relation to the local climatic conditions is required (Jim and Tsang, 2011).

Green roof designs have the potential to mitigate habitat loss in other areas of the city. Two green roofs were designed to mimic the different brown field habitats (brown roofs) in the UK. Recycled materials from building demolition were used as the substrate and the resulting growth was monitored for four years. The Domin-Krajina scale was used to measure the various types of ground-cover along with species inventories. Water availability was one of the strongest influences on green roof development. During the first season annual plants predominated after which they only thrived during periods of. Mosses and *Sedum* spp. steadily proliferated until they became the dominant species. Microhabitats were more robust and better adapted drought disturbance. It appears that there are two hypotheses which can be drawn from these types of research: (i) Coarse substrates provide refuge to plants in periods of drought providing areas of water and being more absorbent. (ii) More fertile substrates have better growth levels where water is readily available, but more sensitive during periods of drought.

Ideally, green roofs should incorporate different substrate types thereby providing multiple microhabitats and improving species diversity (Bates et al., 2013). Another study from Athens investigated the energy and environmental performance of a green roof system. The investigation was carried out in two stages. In the first phase, the study looked at the efficiency of the green roof system; In the second, seasonal cooling and heating were analyzed. The energy evaluation showed that there was a significant reduction in the cooling load in the summer months of the building. This reduction varied between 6-49% for the entire building and between 12-87% for the final floor. Moreover, the effect of the green roof system on the building's heating load is negligible, and any interference in the building envelope can be seen as a major advantage of the system, since it usually leads to increased heating to reduce the cooling load (Santamouris et al., 2007).

2.2 Green Roofs: New Ecosystems to Support Species Diversity

Green roof systems are defined as a complex for growing plants that includes a variety of specific materials with particular functions. The components are layered in the following order: waterproofing, drainage material, filter, growing medium, vegetation and edge protection (Boivin et al., 2001). Green roofs can provide environmental benefits that include increased building insulation, mitigating urban heat islands, providing aesthetic value, reducing runoff and storm water flooding in urban environments, improving air quality by sequestering pollutants, cooling photovoltaic panels to improve their function, and providing habitat for fauna and flora (Blaustein et al., 2016). Increased urbanization has led to significant habitat losses for flora and fauna. Green roofs are a possible area which can help to provide patches of good-quality habitat in urban areas (Colla et al., 2009). Human population growth in urban areas is happening on an extraordinary scale. In 2008, for the first time, >50% of the global human population lived in urban environments. A large proportion of this growth is occurring in developing countries (Goddard et al., 2010).

As a result of this increasing urbanization the conservation and improvement of urban areas in relation to biodiversity and endangered species is becoming ever more necessary (Savard et al., 2000). Increasingly green roofs are being used as a way of compensating lost habitats (Brenneisen, 2006).

There are a number of examples where green roofs have supported good populations of endangered invertebrates (Baumann, 2006). Green roof provide forage and nest sites for bees (Tonietto et al., 2011), habitat for arthropods, (Madre et al., 2013). Additionally surveys carried out in Basel, Switzerland for high levels of biodiversity for birds, spiders and beetles (Colla et al., 2009). In many cities in countries such Japan, Singapore, Germany and Belgium government incentives are given to promote or inforce green roof usage (Mentens et al., 2006).

The aim of this literature review was to investigate the importance of green roof systems on urban biodiversity. A literature review was undertaken to discover the importance of green roof systems on urban biodiversity. And to collate data on the biodiversity value of green roof systems which may sustain species diversity within the urban areas. Most of the published studies were carried out in Europe, USA and Canada. Fifteen original publications were reviewed (Table 2.1).

Table 2.1: Summary with basic characteristics of reviewed publications on biodiversity support of green roof systems

Author (year)	No. of Roofs	Location	Research
1-Madre et al., 2013	115	Paris, France	Arthropods
2-Rosenzweig, 2016	-	USA	Biodiversity
3-Kadas, 2006	-	London	Rare invertebrates and green roofs
4-Starfinger and Institut, 1994	-	Berlin, Germany	Urban biotopes
5-Brenneisen, 2006	-	Switzerland	Designing green roofs as habitats
6-Lundholm, 2015	1	Canada	Plant species diversity of green roofs
7-Blaustein et al., 2016	-	USA	Ecology of green roof systems
8-Goddard et al., 2009	-	UK, London	Biodiversity
9-Faeth et al., 2011	-	New York	Urban biodiversity
10-Colla et al., 2009	3	Canada	Habitat for urban bees
11-Savard et al.,1999	-	France	Biodiversity in urban areas
12-Baumann, 2006	5	Switzerland	Birds on green roof
13-Tonietto et al., 2011	6	USA	Bees on green roof
14-Maclvor and Lundholm, 2010	5	Canada	Insect species
15-Lofvenhaft et al., 2002	-	Sweden	Biodiversity in urban planning

Today, urban ecology is becoming an established sub-discipline of ecology with its own methods and theories (Starfinger and Sukopp, 1994). In many countries, private gardens and/or green roofs collectively provide substantial urban green areas and biodiversity benefits. Green roofs be utilized to provide new habitats in areas which are relatively wildlife poor, additionally they can be designed in such a way that they provide linkages between fragmented habitats (wildlife corridors) (Kadas, 2006). According to this literature review, it is clear that green roofs are important living ecosystems within the urban environment for sustaining biodiversity. Recent publications have shown that green roofs can provide valuable ecosystem for many plant, arthropod and bird species. Green roofs are also very important living areas for rare species and thus contribute to species diversity within urban areas. This research paper provides a broad perspective as to the importance of green roof establishments within cityscapes. Furthermore, it may lead to amendments in building and construction law within the Mediterranean Basin, which is one of the most important global biodiversity hotspots (Myers, 1990).

2.3 Cooling the Cities-Using Green Roof Technologies to Reduce Heat Island

Urban Heat Island (UHI) is heat generation from built structures, as they consume and re-radiate solar radiation, and from anthropogenic heat generation. This results in increased urban temperatures and is known as Urban Heat Island Intensity (UHII). The problem is exacerbated in larger cities and globally the estimated three billion people who reside or work in urban areas are directly affected by this., and is likely to which will be increased significantly increase in the coming years (Rizwan et al., 2008). The levels of UHI mainly depends energy balance modifications which are effected by a number of factors: urban canyons, buildings materials, green roof areas and impervious surfaces that limit evapotranspiration, and reduce albedo effect (Susca et al., 2011).

Heat island effect (HIE) is the most documented phenomenon of climatic change; and is related to higher urban temperatures in comparison to their contiguous suburban or rural spaces. These elevated urban temperatures are a result of anthropogenic heat, solar radiation storage poor city design and a general paucity of green areas (Santamouris, 2014).

It is clear that all the previously mentioned causes have a direct effect on the local climate of urban spaces, particularly in the central parts of cities, causing significant rises in urban temperature (Alexandri and Jones, 2008). Studies on heat island effect are crucial as elevated city temperatures continue to as a result of heat island effect and global warming. Increasing ambient temperatures lead to energy problems endanger vulnerable people within the population and amplify pollution problems. HIE also prolongs the duration of hot spells, increases heat wave frequency and leads to higher levels of energy consumption (Theophilou and Serghides, 2014).

As city temperatures increase through heat island phenomenon and climate change, energy problems will intensify, personal comfort conditions will deteriorate and put vulnerable populations in danger. In order to address these issues a number of mitigation technologies have been put forward. One of the ideas is to improve the albedo of urban areas through the use of roof planting and increasing green areas (Santamouris, 2014). Traditional natural cooling methods have been used from many centuries; however these applications have been scarcely used in the modern era. Air conditioning systems, which greatly increase the energy budget of buildings, have generally replaced natural cooling methods (Barrio, 1998).

However, reverting to natural systems is difficult because of poor urban planning and escalating real estate costs. In many cases the only realistic option is to develop planted roofs, walls and sidewalks. (Onmura et al., 2001). Due to this lack of available space one solution is to turn flat black roofs into green ones (Susca et al., 2011). On white surfaces the heat flux is small and reflectance is high. With green surfaces, heat flux is small through evaporation, and radiation is high (Takebayashi and Moriyama, 2007).

There a number of advantages in using green roofs. A reduction in storm water runoff, protect of roof materials, energy savings, improved air quality increased urban wildlife and a reduction in urban heat island effect (Santamouris, 2014).

Green roofs have the ability to reduce indoor temperatures by between 25 -30 °C. Each 5 °C reduction in room temperature may reduce air-conditioning use by up to 8 %. A 30 % reduction in surrounding air temperatures when a roof is vegetated compared to conventional roof systems, this can lead to energy savings up to 15 % (Getter and Rowe, 2006). The building sector has begun to incorporate green roof designs into some of their project therefore enhancing their ecological and energy saving (Theodosiou, 2003). The European community has recently engaged a research project (ROOFSOL: Roof Solutions for natural cooling) this focuses on theoretical and experimental analysis with the aim of cooling using various roofing designs mainly based on evaporative and radiative cooling principles (Barrio, 1998).

Research shown that green roof which was constituted by a 10 cm deep growing medium layer had increased the thermal resistance and the latent thermal capacity of the roof which covered with more than 21.000 plants of *Sedum* (Susca et al., 2011).

As the evaporative heat transfer on the green roof acts frequently as a heat sink and the radiative energy absorbed by the green roof is smaller than that absorbed by the concrete roof, the energy fluctuations on a green surface can only offer lower surface and air temperatures, when compared to those produced by concrete surfaces (Alexandri and Jones, 2008). Media depth, shade from plant material, and transpiration can reduce solar energy gain by up to 90 % compared with no shaded buildings (Getter and Rowe, 2006).

Example study examined the heat island effect by comparing the mean daily temperature of the two stations – rural and urban – for three different decades, 1983-1990, 1991-2000 and 2000-2010. The heat island effect was also being examined seasonally – winter and summer periods – and with respect to three different categories of wind speed – less than 2.5 m/s, less than 5.0 m/s and less than 10.0 m/s and it was found that the heat island effect was a winter occurrence and the intensity was larger when the wind speed was less significant (Theophilou and Serghides, 2014).

Also it is known that mostly due to the lack of evapotranspiration surface, the temperatures in big cities are higher throughout the year than those in neighboring rural areas, and which is called “heat island” phenomenon (Takakura et al., 2000).

In most urban areas, considerable amounts of vegetation exist mostly in parks, cemeteries or recreational spaces. Although parks manage to lower temperatures within their locality and surrounding areas, they are not capable of thermally affecting the concentrated built areas. By placing vegetation within the intensive built space within urban areas, high urban temperatures can decrease and not only in the detached spaces of parks (Alexandri and Jones, 2008). There are numerous literatures have been reviewed and have been carried out in USA, Europe and Asia on cooling effect of green roof systems on heat island phenomena (Table 2.2).

Table 2.2: Summary with basic characteristics of reviewed publications on heat island effect of green roof systems

Author (year)	No. of Roofs	Location	Research
1- Onmura et al., 2000	1	France	Roof surface temperature
2-Theophilou and Serghides, 2014	1	Cyprus	The meteorological events in the rural and urban parts of Cyprus
3-Alexandri and Jones, 2006	-	UK.	Decrease in temperature in urban canyons with green roofs
4-Takakura et al., 1998	4	Tokyo	Cooling effect on four green roofs
5-Santamouris, 2012	10	Greece	Examination of green roof technologies against heaters
6-Susca et al., 2011	3	Italy	Positive effects of vegetation cover on green roofs in urban heat
7-Theodosiou, 2003	-	Greece	Planted roof passive cooling technique
8-Takebayashi and Moriyama, 2006	-	Japan	Examination of the reflection roof to reduce the heat together with the green roof
9-Barrio, 1997	-	France	Green roofs cooling potential in buildings
10-Rizwan et al., 2008	-	Tokyo, USA, Seoul, Fairbanks, Poland	Examination of urban heat island in general

2.4 Effect of Green Roofs on Indoor Temperatures

The green roofs can be an effective solution for indoor temperatures of the buildings. The warmth of the green roof application compared to the standard roof average effect on heating loads in the climate region 10% more favorable to cooling loads. The effect is at% 5.It is also understood from these results in hot regions green roofs building impact on performance in terms of heating loads it is more recognizable. In cold climates green roof standard heating loads according to the average 2.5% better performance demonstration cooling this performance in their load of 5% in cold regions in hot regions cooling on the contrary a better one in their cargo performance shows. Results in climate zones by comparison heating loads in hot regions 10% more advantageous while in cold regions 3% besides cooling loads in the two regions 5% more advantageous the end result green roofs building energy in performance hot climate of effect compared to cold climate regions it is more positive (Ayçam and Kınalı, 2013).

Kumar and Kaushik (2005) describes a mathematical model for evaluating cooling potential of green roofs and solar thermal shading in Yamuna Nagar (India). This data was then used to predict changes in canopy air temperature, heat flux through roof and indoor air temperature. The accuracy was high when predicting green canopy-air temperature and indoor-air temperature fluctuations (error range ±3.3%, ±6.1%, respectively). Results of this research showed that the cooling potential of green roof was adequate (3.02 kWh per day for LAI of 4.5) in maintaining temperature mean room temperature of 25.7 °C. This model can be easily transferable to different greenhouse and building scenarios. There are only few number of research about green roof effect on indoor temperatures on buildings (Alexandri and Jones, 2008; Santamouris et al., 2007). Therefore this can be one of the key research topic to carry out within the Mediterranean region in future.

CHAPTER 3

MATERIAL AND METHODS

3.1 Research Material

This research has been carried out in Cyprus. Cyprus is the third largest island of the Mediterranean after Sicily and Sardinia. The island of Cyprus is located between 34.33 and 35.41 North latitudes, and 32.23 and 34.55 East longitudes. Cyprus has typical Mediterranean climate. Summer months are drought due to descending air movements. Often summers are hot and dry, winters are warm and rainy. It is known that climate is the most important ecological factor that determines the main characters and distribution areas of plant species and communities on Earth (Günal, 2013). Feasibility analysis of possible extensive roof application was carried out of for Nicosia region. Near East University solar-powered and electric car factory building has been chosen for the analysis which is going to be located within the University campus (Figure 3.1).

Figure 3.1: NEU automobile factory management building

Additionally, during these research opinions of construction companies have been evaluated regarding to green roof systems. In 2017 a total of 10 companies were interviewed and the overview of the companies has been taken about green roof application (Table 3.1). Also, questions were asked to find out whether these construction companies were already experienced of green roof applications within their building projects.

3.2 Research Methodology

Feasibility analysis was carried out for the NEU car factory management building which was planned as 820 $m^{2.}$ Necessary information of the building and the roof has been taken from NEU Design office including the slope details of the roof (Figure 3.2). Cost analysis for extensive green roof model has been carried out for roof layers and the vegetation cover. Green roof layers of the extensive roof model were determined by literature review and information from local companies.

Interviews with construction companies were carried out on the date of 4^{th} of October 2017. In 2017 a total of 10 companies were interviewed and the overview of the companies has been taken about green roof application (Table 3.1). In addition, questions were asked to find out whether these construction companies are applying green roof systems in their design projects.

Table 3.1: The name and location of construction companies interviewed about green roofs

Companies Names	Location
Tüfekçi LTD.	Nicosia
Euro Coast Construction	Kyrenia
Merit Hotel Construction Group	Kyrenia
Aksüt Construction LTD.	Kyrenia
Boryap Building and Business LTD.	Lefke
Ali & Ömer Kofalı Construction	Nicosia
Arpalıklı Infrastructure and Construction LTD.	Kyrenia
Blue Lotus Construction LTD.	Famagusta
Ümran Duman Construction Company	Kyrenia
Eğilmez Construction LTD.	Morphou

The phone calls done in order to gather information about the green roofs by the same person by asking set of standard questions between the hours of 12-00 and 18-00. This work, which was conducted by telephone interview, was carried out within one day. But every company could not be reached. For this reason, the research continued until the interviews completed with 10 companies. A number of questions were asked in the telephone survey. The following questions were asked:

1-Have you ever made a green roof before?

2-What do you think about green roof designs?

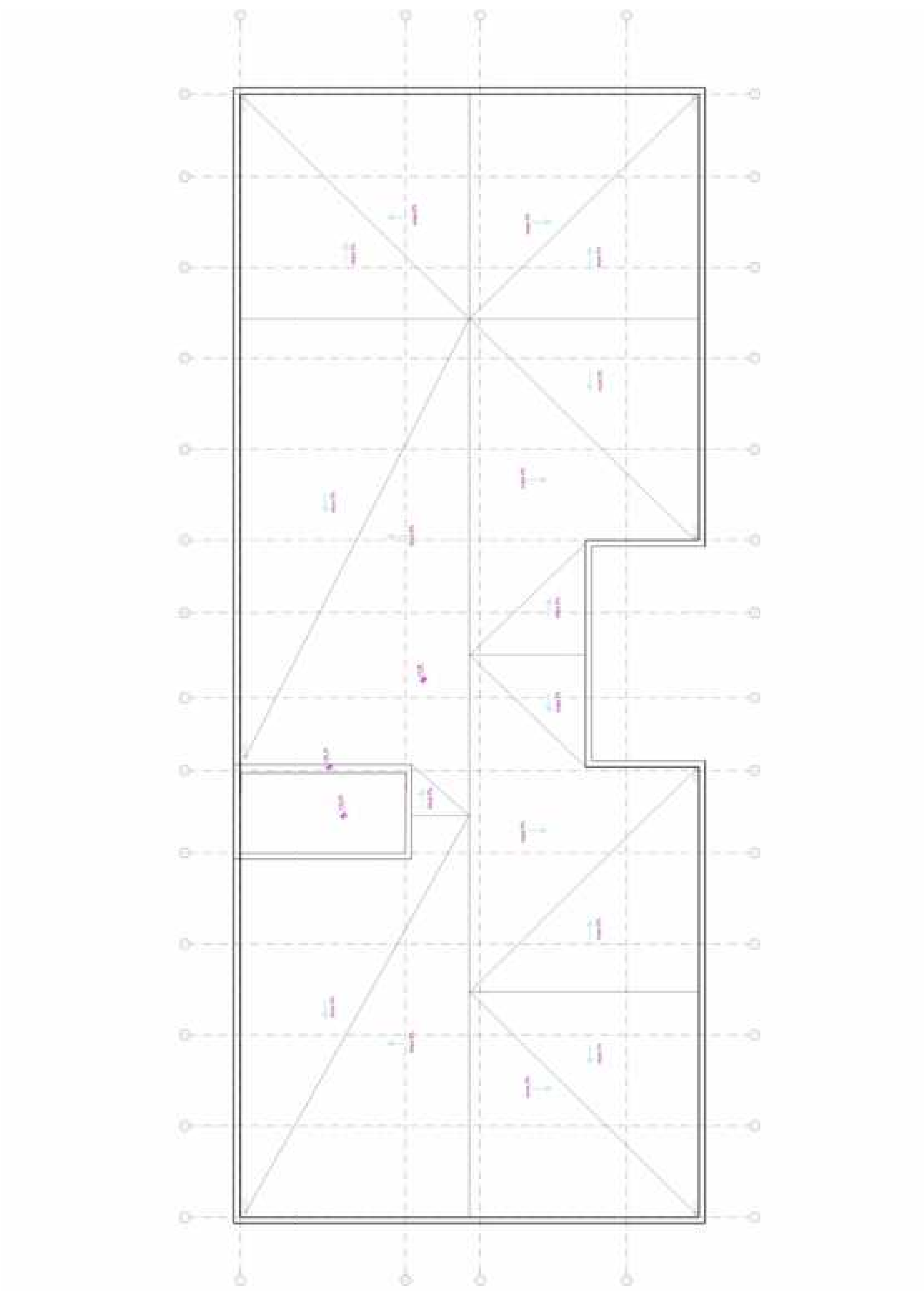

Figure 3.2: 2% slope project plan provided by NEU Design

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Telephone Survey on Green Roof Systems

It was determined that only 2 of the 10 construction companies chosen randomly and reached the end of their searches had green roof applications installed. It was learned that the other 8 companies did not have such an application. If it were to give a percentage result, 80% of the companies had green roof application. 20% have not yet done so. Although the companies were concerned about the implementation, they expressed a positive opinion but did not see much demand from the customers (Table 4.1).

Table 4.1: Green roof application rate of companies (%)

Participants	**Yes**	**No**
Companies	20%	80%

As a result of the second question, which led to the views on the implementation of the green roof, 8 positive opinions emerged. One of the other 2 companies stems from the negative thoughts that this green roof application could not cure. However, the proper application of this practice has proven to be inadequate, especially when considering the extensive green roof application to be investigated. So it would be correct to say that this company which is negative about this practice is totally unconscious about the subject. While I would say 80 percent positive in percentage, 20 percent think negatively, knowing that there will be many benefits to the neighborhood while trying to implement it (Table 4.2).

Table 4.2: Companies' thoughts about the application (%)

Participant	**Positive**	**Negative**
Companies	80%	20%

4.2 Cost Analysis: Green Roof Layer Application

A number of studies have been carried out for the application of the green roofs which have been investigated and which were very useful. The management area of the NEU automobile factory was selected as the application area. Negotiations were held with the NEU design team on campus. The type determined for green roof application is extensive green roof type. Extensive green roof can be called superficially planted green roof. This type of roof; plant growth layer is a light weighted system with a depth of 15 cm or less, with short-lived plants growing or spreading horizontally on this layer, often inaccessible. Strong and drought tolerant plants are used the plant. These plants; mosses, some drought-tolerant meadows and perennial grasses, especially moss / sediment, sediment / moss / herbaceous plant, sediment / meadow / herbaceous plant and meadow / herbaceous plant mixture can be designed together. These plants are easy to cultivate and maintain, and low cost. In this type of green fence, the drainage layer thickness is about 3 cm, but in a single layer system there is no need for such a layer. Even irrigation system is usually unnecessary.

Normally the roof pitch can be between 2% and 70%, in exceptional cases up to 100%. However, the extremely superficial flow rate of precipitation water causes erosion in steep slopes with a slope greater than 35%. It is necessary to take measures against this erosion. The roof load of this type of roof is 60-240 kg/ m^2. The water on the roof will flow to the sides of the roof by the inclination. Then, the rainwater in the edges will collect in the gutters. With the last rainwater pipes, the water will be transmitted down. Another important application to be aware of is the parapet system. This system should be made according to the rules set by the legal standards according to the researches carried out. The height of the parapet should be at least 90 cm above the ground we are pressing. In other words, it should be 90 cm above the level of the vegetative layer in the top layer of the green roof layer.

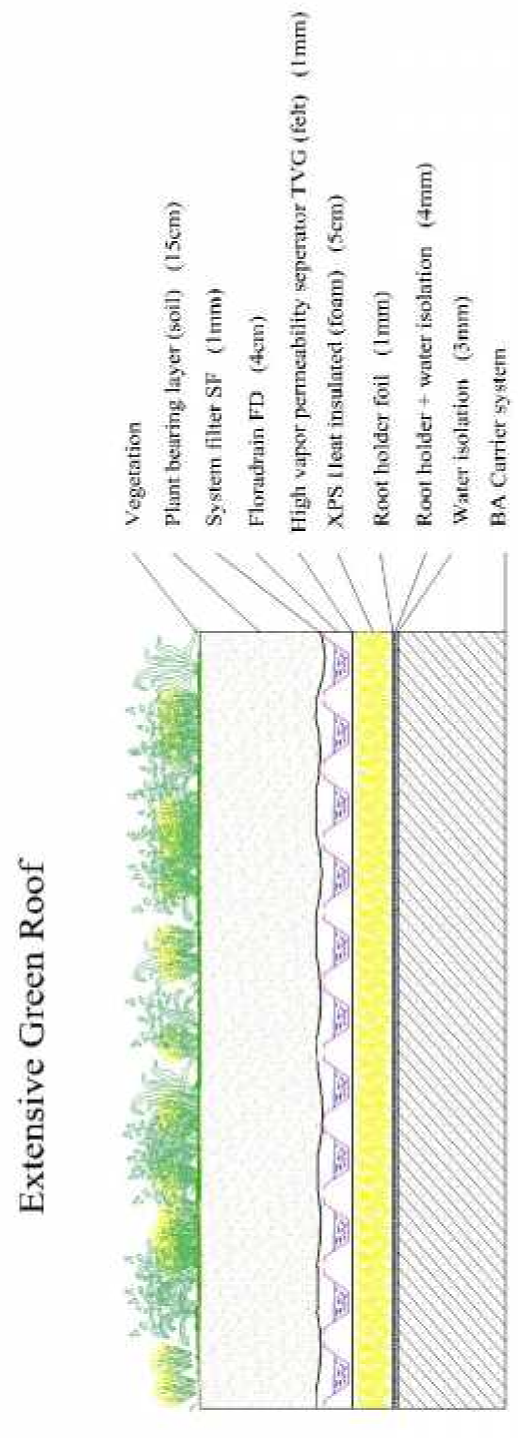

Figure 4.1: System layers

The administrative building planned for the application is 820 m². Therefore, the amount of the specified layers is calculated according to this area. For this information, assistance was obtained from the companies implementing the green roof. And the following table is the result of the demonstration cost analysis (Table 4.3).

Table 4.3: Cost analysis for 820 m² green roof system in Nicosia

Stock code	Stock type	Stock unit	VAT %	Quantity	Cost	Total (TL)
CCNB011 G	BITULINE ANTIRACİNE EP400	m²	10	910.000	20.27	18 445.70
CCNB017	BITULINE PRIMA PP300	m²	10	910.000	12.32	11 211.20
CCNB000	BITULINE ASTAR 17 KG	TKN	10	10.000	39.77	397.70
DWF 25A	FOAMBOARD 2500 L-K 5/60/120CM	PIECE	10	1.150.000	18.30	21 045.00
CCN7ZT	ONDUGREEN EXTENSIVE PLANT CARRIER	m³	10	123.000	642.56	79 034.88
IT TD KT	TEKDRAIN PE ROOT HOLDER FOIL 380gr/m²	m²	10	1.000.000	6.09	6 090.00
IT SF	TECHNICALSYSTEM FILTER 110gr/ m² 1100PP	m²	10	900.000	1.65	1 485 00
ITTD GF40	TEKDRAIN GF40 GREEN ROOF DRAINAGE LEV. 250kN/ m² net	m²	10	820.000	33.06	27 109.20
IT GT	GEOTEXTILE FELT 500gr/m² MOISTURE HOLDER	m²	10	900.000	5.54	4 986 00

TOTAL	
Sum of goods	169 804.68 TL
VAT	15 436.79 TL
Grand total	169 804.68 TL

4.3 Green Roof Vegetation

The top roof of the green roof system designed for the management building of the NEU automobile plant will be planted. These plants will be suitable for Mediterranean climate. This will ensure sustainability. Some features have been taken into account when choosing plants. Among these properties are plants that do not require much water and that can survive in arid climatic conditions, sun-resistant plants. For this reason, the plants to be used in green roof application are; *Sedum angelina, Sedum spurium, Thymus vulgaris, Santolina spp.* and *Gaura lindheimeri.*

Sedum angelina has a wide variety of cultures and cultivars. Most of the 500 well-known crawl species are pretty dubious, succulent plants spreading through soil shoots. The length is 5-8 cm. It does not. Herds are green or semi-annual green perennial plants. Leaves are fleshy, various forms and large. Red leaves turn red in winter. It is drought resistant plant species. Also can develope well in poor soil conditions. *Sedum spurium* is perennial, scullent, frequent body, low-tall, creepy body, 10-15 cm long, green herbaceous plant. It blooms in spring and summer. It grows in sunny places and in temperate places. *Thymus vulgaris* is known as a medicinal plant among the people.

There are many benefits. Turkish name is kekik. Leaves are egg-shaped, fragrant, pink-white flowers. It likes sunshine and warmth. *Santolina spp.* is a genus of within the chamomile family, origin of the western Mediterranean region. They are small evergreen shrubs growing 10-60 cm (4-24 in) tall. *Gaura lindheimeri* can grow 40-140 cm. It grows pretty fast. Straight green - red blend has variegated leaves. The leaves are very decorative. It is resistant to summer heat and winter cold.

Table 4.4: Cost analysis for the vegetation

Plant name	Weight (cm/m)	Number	Cost (TL)	Total (TL)
Gaura lindheimeri	0.5-1 m	200	7-10	2000
Santolina spp	24 cm	800	5	4000
Sedum angelina	10-15cm	500	5	4000
Sedum spurium	10-15cm	500	5	4000
Thymus vulgaris	25 cm	800	7	5.600
				TOTAL (TL) = 19.600

In the study for green roof application, planting was taken separately. The seeding section forms the top of the layers that make up the system. The carrier just below is above the soil. 5 kinds of plants were selected. These; *Sedum angelina*, *Sedum spurium*, *Thymus vulgaris*, *Santolina* spp. and *Gaura lindheimeri*. These preferred plants are suitable for Mediterranean climate conditions. They hardly need any water. Fertilization is enough per year. They are resistant to arid conditions. They also love warmth, so they can live directly in the sun. The cost analysis of vegetation cover was also determined. The calculation was made by interviewing several nurseries located in Cyprus. The size of the application area of 820 m^2 is taken into consideration for the vegetation cover cost. According to the account made, the number of plants and the price for the each plant used are listed in the table above (Table 4.4 and Figure 4.1).

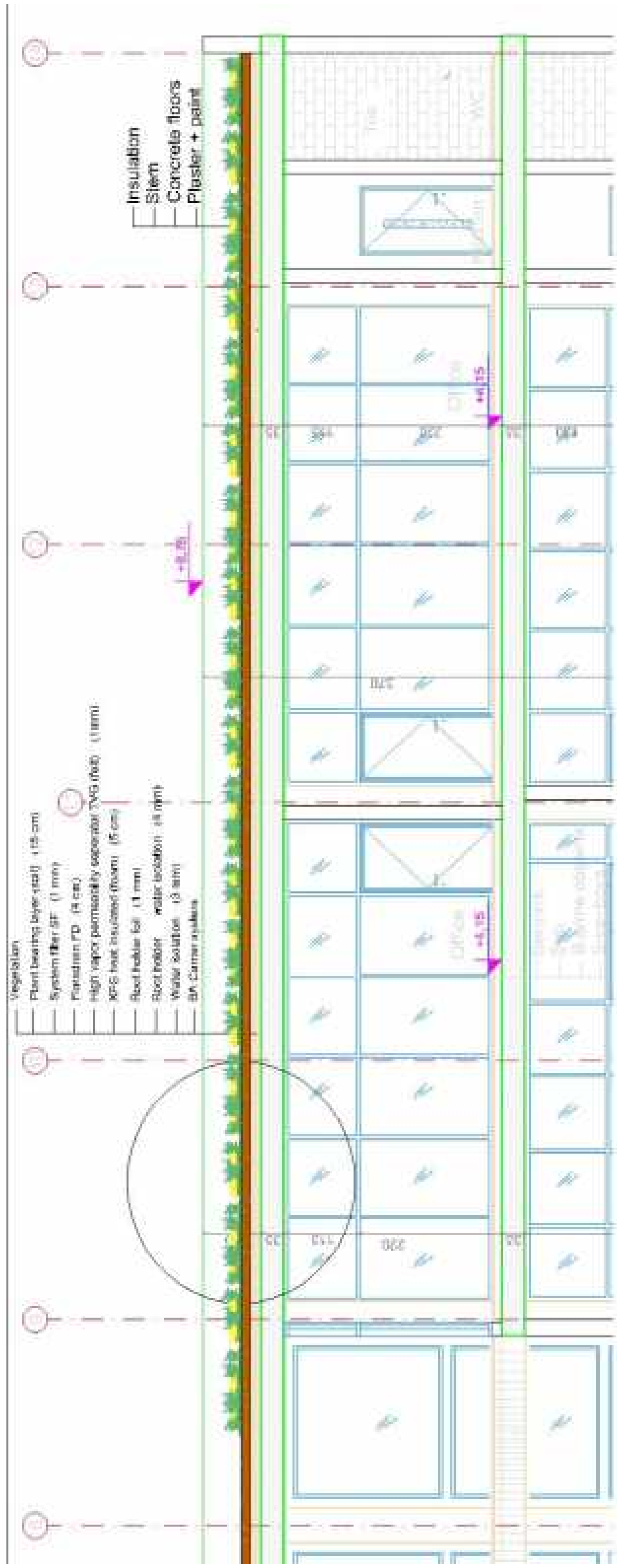

Figure 4.2: Vegetation of green roof, side section

Today, urban ecology is becoming an established sub-discipline of ecology with its own theories (Starfinger and Sukopp, 1994). In many countries, private gardens and/or green roofs are the major part of urban green space and can provide significant biodiversity benefits. Green roofs may provide new habitat niches that of lack wildlife spaces. They act as green corridors connecting fragmented habitats, facilitating wildlife movements and distribution. Additionally, they are serving as micro habitats for rare species (Kadas, 2006). Use of green roof technology is becoming increasingly widespread throughout the world because of its several environmental benefits. The ability of a green roof to retain storm water and limit the amount of fertilizer in the effluent flow. Differences in water retention can likely be attributed to substrate depth, rather than drainage system or vegetation type.

According to this thesis, green roof designs are important for sustainability in the Mediterranean urban environment. For this reason, this study was planned to be implemented in the Mediterranean climate of Cyprus in near future within the NEU campus. According to research result 820 m^2 roof will cost approximately 190,000 TL for the green roof layers and vegetation cover of extensive green roof system. This is shown that extensive green roof application would cost around 232 TL per square meter in Cyprus climate conditions. It is very important to design green roof systems with properly selected plant varieties for sustainability.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this research, the possible applications of extensive green roof systems in Cyprus have been revealed. Green roofs are important components for urban areas and can be used as mitigation measures against climate change in urban areas and additionally improving the quality of urban environment. This research was the first detailed feasibility analysis research on application of extensive green roof systems in Cyprus. Results reveal that very few construction companies are aware of the benefits of green roof systems and again very few of them applied these systems into their projects. The feasibility analysis results indicated that the costs involved in extensive green systems are negligible for Cyprus climate conditions. Local authorities should be aware of green roof systems may alleviate the impact of extreme weather conditions when applied to dense urban areas. In conclusion, extensive green roofs based on lightweight substrates with good water retention capacity in conjunction with drought tolerant plants, could easily be adapted to cities in the Mediterranean region.

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