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Positive effects of vegetation: Biodiversity and extensive green roofs for Mediterranean climate

Sinem Yıldırım, Özge Özden *

Department of Landscape Architecture, Near East University, Nicosia, Cyprus

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ABSTRACT

Green roofs are important green spaces in order to improve vegetated area in urban landscapes. They can support ecosystem functionality, including stormwater management, cooling and insulation of buildings, moderation of urban heat island effect, contribution to human health and habitat provisioning. In addition they provide habitats in areas deprived of natural wildlife areas, providing green corridors linking fragmented existing habitats, improve wildlife movement and dispersal, thereby increasing population connectivity and act as refuges for declining or rare species. Unfortunately populations living in urban areas continue to rise and are expected to reach 61% in 2030, which is likely to negatively impact urban green spaces. The aim of this research 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. Additionally, feasibility analysis of the planting project of possible extensive green roof application in semi-arid climatic conditions of Cyprus was carried out. Positive effects of the plants on the roof are also discussed. Feasibility analysis was carried out for the NEU car factory management building which was planned as 820 m². The following plant species have been suggested for the vegetation of sustainable green roof system in Cyprus; *Sedum angelina*, *Sedum spurium*, *Sedum glaucophyllum, Thymus vulgaris*, *Santolina* spp., *Gaura lindheimeri*, *Lavandula angustifolia, Rosmarinus officinalis.* According to research results 820 m² of extensive green roof will cost approximately 37107 Euro. Under Cyprus climatic conditions, this cost analysis estimated that extensive green roof application would cost around 49 Euro per square meter. This research provides valuable information for the importance of green roof establishments within the Mediterranean cityscapes and also has suggestions of vegetation types and roof layers for future green roof projects for the Mediterranean region.

1. Introduction

Green roof systems are defined as a complex systems 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 stormwater 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). Living roofs also provide aesthetic and psychological benefits for people in urban areas. Even when green roofs are only accessible as visual relief, the benefits may include relaxation, which can improve human health. Other uses for green roofs include urban agriculture: food production can provide economic and educational benefits to urban dwellers. On the other hand living roofs also reduce sound pollution by absorbing sound waves outside buildings and preventing inward transmission (Oberndorfer et al., 2007). At the beginning of the twentieth century, 15% of the world population lived in cities. Currently, about 50% of the world population lives in urban areas, which is approximately 2.8% of the total land of our planet. The increase in urban inhabitants has led to urban sprawl, especially in

* Corresponding Author.
Email Address: ozge.fuller@neu.edu.tr (Ö. Özden)
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developing countries (Susca et al., 2011). Increasing urbanization of many regions of the world has resulted in the decline of suitable habitat for wild flora and fauna. Although much is known about the application of green roofs across Europe, much less is known about their application across Mediterranean diverse ecological regions (Fioretti et al., 2010). When considering many decisions required in applying green roof technology to a specific place, there are few choices more critical to their success than the selection of appropriate vegetation. They conducted a review of green roof research to investigate what is known about the application of plants on green roofs across North America and their ecological implications. Results indicate that investigation sites across ecoregions begin to reveal differences in plant survival. Although ecological investigations are limited, their results show improved plant performance and ecological services with diverse green roofs. Ecosystem services from green roofs can be improved by planting certain life-form groups in combination, directly contributing to climate change mitigation and adaptation strategies. The strong performance by certain mixtures of life-forms, especially tall forbs, grasses and succulents, warrants further investigation into niche complementarity or facilitation as mechanisms governing biodiversity-ecosystem functioning relationships in green roof ecosystems (Lundholm et al., 2010). In addition green roof plant species diversity also improves ecosystems multifunctionally (Lundholm, 2015). Urban growth is occurring at an unprecedented scale. In 2008, for the first time, >50% of the global human population lived in urban environments. Much of this urbanisation is occurring in developing countries, which are predicted to harbour 80% of the urban population of the world by 2030 (Goddard et al., 2010). As more and more people live in cities, restoration, preservation and enhancement of biodiversity in urban areas become important (Savard et al., 2000). Green roofs have been suggested as a potential avenue to provide patches of good-quality habitat in highly developed regions (Colla et al., 2009). Well-designed green roofs can provide habitat compensation for rare and endangered species affected by land-use changes (Brenneisen, 2006). Already, numerous IUCN Red List species of spiders and beetles have been found on green flat-roof habitats in Europe (Baumann, 2006). Furthermore, green roofs are potentially valuable sites for bee conservation in urban areas, particularly if planted with diverse native forbs to provide foraging resources, and designed to accommodate bees with different nesting habits (Tonietto et al., 2011). There is a great interest in increasing the diversity of plant species with a particular focus on the use on native plants (Butler et al., 2012).

Furthermore, green roofs can be even more important for other organisms, such as arthropods, that need small habitats to maintain viable populations (Madre et al., 2013). For example, in Basel, Switzerland, surveys of birds, spiders and beetles on green roofs found high diversity levels for all groups, including many species considered rare or threatened (Colla et al., 2009). In some highly urbanized societies like Japan, Singapore, Germany and Belguim the advantages of green roofs have already resulted in incentives from the government to encourage or even impose the use of green roofs (Mentens et al., 2006). Due to increasing human population cities are rapidly developed and largely covered with concrete. Therefore, green spaces becoming less and less each day and also fragmented with the cities. There has been noticeable urbanization in Kyrenia, Nicosia and Famagusta regions in Cyprus. In many countries private gardens and/or green roofs collectively provide substantial urban green areas and biodiversity benefits. Green roofs can provide new habitats in areas which are relatively wildlife poor; additionally they can be designed in such way that they provide linkages between fragmented habitats as a wildlife corridor (Kadas, 2006). The aim of this research was to investigate the importance of green roof systems on urban biodiversity. For this reason a literature review was undertaken to discover the importance of green roof systems on urban biodiversity. Also in this research it is aimed to identify the main factors when applying green roof systems for Cyprus which has a Mediterranan climate conditions. Additionally with this research feasiblity analysis of possible green roof application has been carried out.

2. Material and methods

The research on feasibility analysis of green roof application 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 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 (Fig. 1).

Cost analysis for extensive green roof model has been carried out for roof layers and the vegetation cover. A literature review was undertaken to collect 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 1).

Fig. 1: NEU car factory management building (NEU DESIGN in 2018)

Necessary information of the building and the roof has been taken from NEU Design office including the slope details of the roof . 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 4th 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 2). In addition, questions were asked to find out whether these construction companies are applying green roof systems in their design projects. 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 Table 2. 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?

In addition, green roof planting project planned and designed to be applied in the future is drawn. Roof model including suitable plants has been developed for Mediterranean climate.

Table 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 Sukopp (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. (2010)	-	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. (2000)	-	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- MacIvor and Lundholm (2010)	5	Canada	Insect species
15- Löfvenhaft et al. (2002)	-	Sweden	Biodiversity in urban planning

Table 2: The name and location of construction companies interviewed about green roofs

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

3. Results and discussion

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 are a major component of urban green space and can provide considerable biodiversity benefits. Green roofs may provide new habitats in areas that currently lack suitable wildlife spaces, act as green corridors linking existing habitats, facilitating wildlife movements and dispersal, additionally, serving as refuges for declining and rare species (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 (Coffman, 2007;

Lundholm et al., 2010; Rosenzweig, 2016). During this research the administrative building planned for the application was for 820 m^2. Therefore, the amount of the specified layers is calculated according to this measurement. Detail drawing plan for roof layers designed for this green roof project (Fig. 2). In order to find out layer costs information, assistance was obtained from the companies implementing the green roof systems in Cyprus. Also relevant companies cost information has been checked on internet sources or brochures. Result of the cost analysis can be seen in (Table 3).

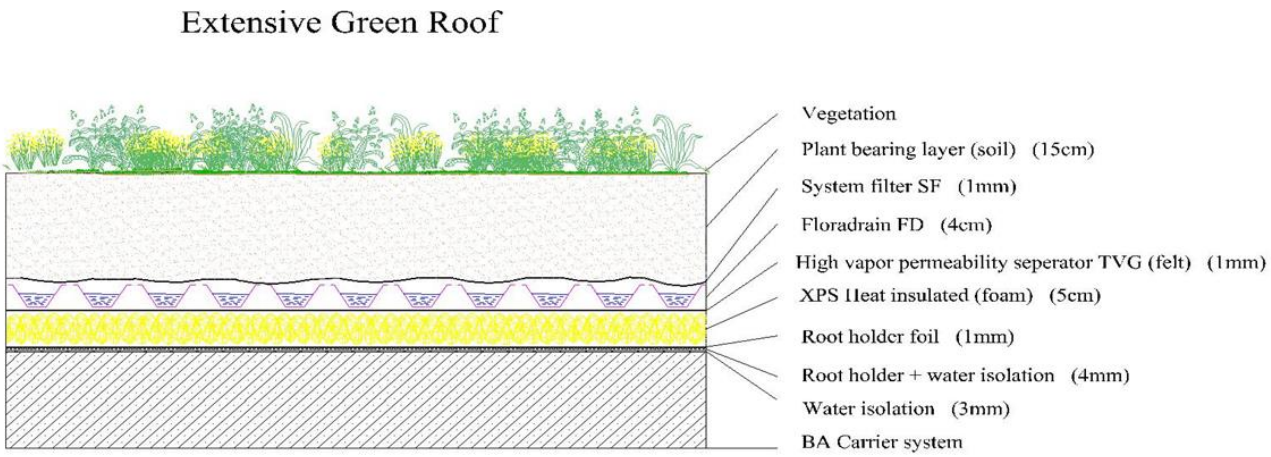

Fig. 2: Proposed green roof system layers

Table 3: Cost analysis for 820 m^2 green roof system in Nicosia

Stock type	Stock unit	VAT %	Quantity	Cost (EURO)	Total (EURO)
BITULINE ANTIRACİNE EP400	m^2	10	910	4	3640
BITULINE PRIMA PP300	m^2	10	910	2.4	2184
BITULINE ASTAR 17 KG	TKN	10	10	7.80	78
FOAMBOARD 2500 L-K 5/60/120CM	PIECE	10	1150	3.60	4140
ONDUGREEN EXTENSIVE PLANT CARRIER	m^3	10	123	128.40	15793
TEKDRAIN PE ROOT HOLDER FOIL 380gr/m^2	m^2	10	1000	1.20	1200
TECHNICALSYSTEM FILTER 110gr/ m^2 1100PP	m^2	10	900	0.33	297
TEKDRAIN GF40 GREEN ROOF DRAINAGE LEV. 250kN/ m^2	m^2	10	820	6.60	5412
GEOTEXTILE FELT 500gr/m^2 MOISTURE HOLDER	m^2	10	900	1.10	990
				Total (incl VAT)	37107

According to literature review we found that growth media (plant bearing layer) perform best in 4-15 cm for mixed vegetation (scullents and herbaceous) (Boivin et al., 2001). On the other hand Dunnett and Kingsbury (2008) stated that there are two main sets of criteria to consider for the plant selection off green roofs: Firstly plants should be chosen that they will thrive in the conditions expected to triumph at the site. Secondly, visual appearance of vegetation is also important part of an overall design concept. Survival of the plant species in certain climatic conditions is vital for sustainable green roof systems; therefore particular attention is necessary for worst case weather scenarios. According to Dunnett and Kingsbury`s criteria's following plant species have been suggested for the vegetation of sustainable green roof system in Cyprus; *Sedum angelina*, *Sedum spurium*, *Sedum glaucophyllum, Thymus vulgaris*, *Santolina* spp., *Gaura lindheimeri*, *Lavandula angustifolia, Rosmarinus officinalis.* Sedums are perfect plants in the roof greening world as they can store water in their leaves and are shallow-rooted, whereas many plants of dry habitats are able to grow here they do because of having immensely deep root systems (Dunnett and Kingsbury, 2008). *Sedum* genus has a wide variety of cultivars. Most of the well-known crawl species are pretty dubious, succulent plants spreading through soil shoots. They are drought resistant plant species and also can develop well in poor soil conditions. For example *Sedum spurium* is perennial, scullent, frequent body, creepy body, 10-15 cm long, green succulent plant. It blooms in spring and summer. It grows in sunny places and in temperate places (McHoy and Donaldson, 2010). It is known that there are also native Sedum species growing naturally in Cyprus (Viney, 1994). *Thymus vulgaris* is known as a medicinal plant among the people. Its` 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 (Barron, 1999). There is also native Thymus species occuring in Cyprus called `Thymus capitatus` growing in lowland garigue ecosystems. Gaura lindheimeri can grow 40-140 cm. It grows pretty fast. It is resistant to summer heat and winter cold. Lavandula angustifolia and Rosmarinus officinalis are aromatic shrubs, they can grow up to 2m, they are quick growing, evergreen and drought tolerant plant species (Latymer, 1990).

During this research, 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. 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 37107 EURO for the green roof layers and vegetation cover of extensive green roof system. This result indicated that extensive green roof application would cost around 49 Euro per square meter in Cyprus climate conditions. It is very important to design green roof systems with properly selected plant varieties for sustainability. According to the account made, the number of plants and the price for the each plant used are listed in Table 4.

Proposed green roof design for semi-arid Mediterranean climate condition of Nicosia can be seen in (Fig. 3). With this proposed green roof design 'ecological' and 'sustainable' green roof system has been developed which will not require much input of resources. NEU car factory management building roof design will not be intended for regular human usage or not even be intended to be seen on a regular basis. Although it will not require regular maintenance simple walk passage still designed for good access to the different part of the roof. As it can be seen in Table 4 mixture of herbaceous and woody plant material suggested for design. This type of mixed vegetation cover will sustain biodiversity and habitat for different organisms.

Table 4: Vegetation cost analysis

Plant Name	Height	Number	Cost (Euro)	Total (Euro)
Gauralindheimeri	0.5-1m	100	2	200
Santolina spp.	24 cm	500	1	500
Sedum angelina	10-15 cm	800	1	800
Sedum spurium	10-15 cm	500	1	500
Thymus vulgaris	25 cm	600	1	600
Lavandula angustifolia	1m	30	2	60
Rosmarinus officinalis	1-1.20 m	85	2	170
Sedum glaucophyllum	10-18 cm	600	1	600
				3430

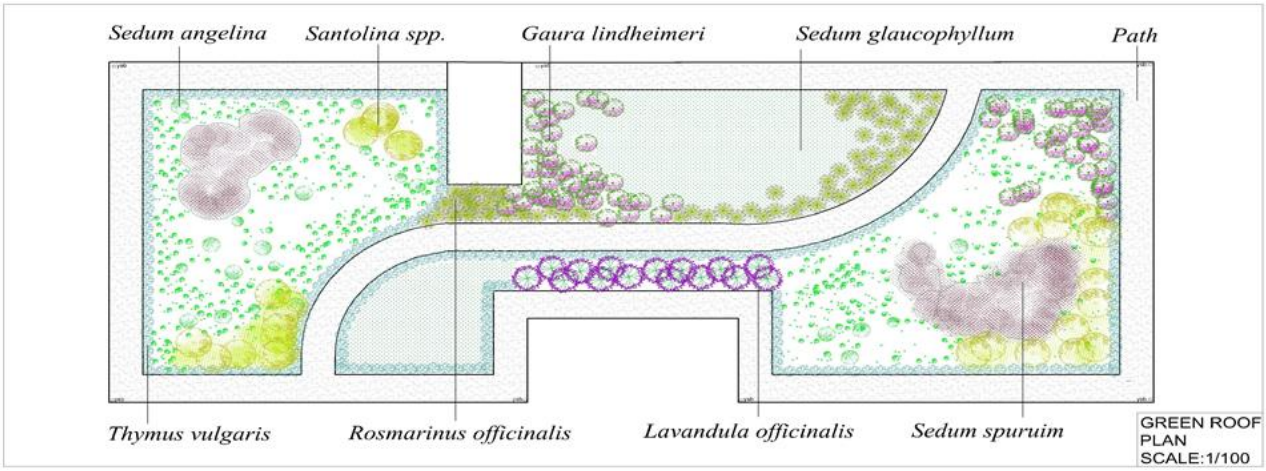

Fig. 3: Green roof vegetation design for NEU car factory management building rooftop

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). In addition, plants suitable for the Cyprus climate condition have been determined for the extensive green roof which was planned to be applied.

4. Conclusion

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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