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# Habitat Effect on Urban Roof Vegetation

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**Abstract:** Urban growth has been fast for decades. Because money is very important in this urban-based world, humanity focuses on economic development, and is often too busy to deal with sustainability. Therefore, in a world that is constantly changing, creating sustainable cities that contain a diverse range of habitats supporting plant establishment is essential. Some surprising urban habitats in which plants can grow, such as cracks on pavements and walls, rocky areas, abandoned places and roofs might be extremely important for sustainability, while urban spaces are under artificial pressure. In this study, which suggesting a method to create more sustainable green roofs for urban areas, and considering roof vegetation is already important for supporting the ecology of urban areas, we surveyed 37 roofs in an urban part of Trabzon city focusing on the habitat effect. We found 51 plant species growing on these 37 roofs, and determined five different roof vegetation typologies in the research area. The main goal in any artificial green roof is to cover roof surfaces with vegetation, and success is considered a perfect coverage rate. We found roof surface size, species richness, size of the sunlit part, daily sunlight duration, and depth of the substrate are the most effective habitat attributes on vegetation coverage on rooftops in the research area.

**Keywords:** green roof; roof vegetation; habitat effect; Trabzon city

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## 1. Introduction

Even though their ecosystems are always under strong artificial pressure, cities still have many dynamic habitats. No matter how challenging their ecological conditions are, nature's hard-working ground covers and cliffhangers, including mosses, lichens, ferns, herbs, shrubs and even trees, begin to colonize vertical and horizontal surfaces of cities. Because surviving in urban environment for them is diversionary, they might not be very significant, as city life is often against them with all its dynamics: a thousand people can walk through a newcomer herb in a pavement joint to catch a train, or a man can try to get rid of moss colonization on their roof to solve a drainage problem. However, if it were possible to find an area that has been isolated in an urban environment, away from the city life and all its artificial components since the 1970s, we would probably be able to see many rooftops covered with natural vegetation, up to 100 percent. It would be quite interesting to find many natural green roofs in an urban core, which shows great potential, in a city without artificial roofs.

As a phenomenon that is considered quite new despite the fact that it has existed for thousands of years, vegetated rooftops—or green roofs—have become very popular, primarily because they seem to have ideal solutions for some recent important ecological problems, especially in urban areas. The history of green roof nearly encompasses the history of civilization. Ornamental roof gardens were used in ancient civilizations of the Tigris and Euphrates River valleys and in Rome [1]. Moreover, the hanging gardens of Babylon in the seventh and eighth centuries B.C. were actually planted on rooftops, providing a famous example of this practice [2].

As for contemporary extensive rooftops, they originated at the turn of the 20th century in Germany, where vegetation was installed on roofs to mitigate the damaging physical effects of solar radiation on the roof structure. Green roof coverage in Germany now increases by approximately 13.5 million square meters per year [3]. There are two kinds of green roofs: intensive and extensive. The first one has deep growing mediums and a more diverse plant community, but structural load and costs are often high [4], while the second generally means shallow substrate often up to 15–20 cm and no woody plants on it. However, plants on extensive green roofs must be strong against difficult conditions as the shallow substrate and full exposure to the environment permits periodic drought and rapid fluctuations in soil moisture [4,5] Being less costly and material intensive, extensive green roofs are the focus of most research studies [6], including this one.

Because more and more people prefer living in big cities to earn their livings, housing demand in urban areas increases, making building spaces scarcer. Residential and industrial areas often replace green patches in cities. This process, ironically, creates less attractive and ecologically unhealthy urban environments for those who create the demand on cities to live better. Principally, rooftops might substitute a green area that buildings already replaced on the ground to reduce the impact on the environment. As they may be one of the most promising ecological engineering techniques to increase green surfaces [7], green roofs have a great importance for ecological life quality in cities. They do this in several ways. For instance, evapotranspiration, together with water storage in the substrate, leads to more effective stormwater management [8]. Rooftops not only divert up to 100% of stormwater and increase downstream erosion, but also account for up to 60% of building cooling load, contributing a significant source of building energy consumption [9]. Other potential benefits include green-space amenity, habitat for wildlife, air-quality improvement, and reduction of the urban heat-island effect [10]. In addition, green roof vegetation offers habitats and food sources that support a range of local invertebrate [11]. Many bird species can reach green roofs in urban areas; some can utilize these roofs for feeding and breeding [12]; and some species such as the black redstart (*Phoenicurus ochruros*) can be observed [13]. Therefore, it is possible to say green roofs can increase biodiversity value [3,14].

Apart from their ecological importance, green roof might have some important functions that any roof type should already have had. Green roofs have been shown to increase sound insulation [15], fire resistance [16], and the longevity of the roof membrane [17], which make them not only ecologically but also economically sustainable and reliable constructions against some disasters and deterioration. It is even possible to see some green roof usage for mystical reasons in history. Emperor Charlemagne recommended sempervivum species be grown on top of houses to protect against lightening and witchcraft in the 9th century [18].

For all these reasons, humanity has always tried to adapt plants on their rooftops. As rooftop conditions are challenging, and typical rooftop substrate can ecologically be considered drought, shallow and relatively poor in organic material, a list of some hardy plant species including sedums, sempervivums and several other succulents is very popular, especially among individual green roof holders. Even though succulent plants are generally considered the most appropriate plants to apply on extensive green roofs [8], and these hardy and—depending on the location—mostly exotic species contribute to awareness of green roof all over the world, they might not be enough to establish a sustainable green roof. In fact, green roof communities are dynamic and vegetation is likely to change from the original composition [19]. Rooftops are open habitats for many native species and wild plants generally do not wait that long to colonize them. While these wild plants can find "brand-new" traditional rooftops as habitat for themselves, it is also possible to identify some colonized species among planted green roof plants [20].

Having focused on this volunteer plant potential, we considered if this power should be used more efficiently so that ecological quality of cities is higher. In fact, using native species in urban environment is often supported by many scientists, basically because of their higher adaptation capacity and great contribution to biodiversity in artificial areas, as they are supposed to grow and survive in their natural ecological conditions. However, because it is not that easy to find real rooftops, having ideal conditions, covered with natural vegetation in urban areas, some different techniques such as the habitat template hypothesis [21] were developed to find appropriate species for green roof projects. These techniques are generally based on comparing rooftops to some natural habitats having similar ecological characteristics. While mostly rocky environments, free draining dunes, limestone pavements and open areas on very shallow and nutrient poor soils can be evaluated as extensive green roof conditions and studying the native plant species composition in these habitats is useful [8], undoubtedly no habitat can be more representative of something than itself. In addition, some regions may not have native vegetation that can withstand the stress occurring on an extensive green roof [10], and some ecological characteristics are difficult to replicate on roofs [22]. In addition, sometimes native species that seem suitable at the beginning cannot adapt to rooftops conditions very easily. For example, Monterusso et al. [23] tried to prove establishment and persistence of some native and exotic taxa for non-irrigated extensive green roofs having 10 cm of growing media in Michigan, and they reported only four of 18 survived after three growing seasons. As Madre at al. [14] mentioned, wild plant communities on green roofs remain poorly described, and there is a need for a spatial extensive survey on numerous sites to consider their potential role in urban biodiversity conservation. Therefore, even if some plant species occurring in certain ecological conditions can clearly be used as green roof plants, evaluating the performance of the native plants on real and untouched rooftops would literally make sense.

This study is focused on a survey of the colonizing plant communities on 36 ordinary roofs, calling them "natural urban green roofs", within a field that has been kept away from artificial effects because of its former long-held military status, in an urban environment. Addressing the following questions is the main purpose of this study: (I) Which species can colonize on a traditional and ordinary roof in an urban environment? (II) Do these species create natural plant composition typologies on the roofs? (III) If yes, what are the visual characteristics of these typologies? (IV) What are the ecological components that these typologies depend on? (V) What are the impacts of these results on the fields of sustainable urban green roof systems?

## 2. Material and Method

### 2.1. Study Area

This study was conducted in a slightly woody and former military area in Camoba district of Trabzon city, Turkey (Figure 1). It has a total surface area of 103,000 $m^2$ and the lowest and the highest points of the research area are 215 m and 280 m, respectively. When the area was first declared a military field is officially unknown; however, the first available official record confirming the martial status is the municipal development plan (MDP) in 1989, and this plan is known to be copied from the former one prepared in 1978, which officially does not exist anymore. It is confirmed by the local people that the area was declared martial and surrounded with a stone wall and metal fence combination, of which the average height is 2.5 m, and closed to the public in the second half of 1970s. Within a few years, the main character of the area started turning into more natural habitat, primarily because artificial effects were decreased as the area had always been secured by a group of soldiers maintaining a watch. As a result, it was declared special protection area by the Natural Habitat Conservation Board in 1991 and martial function in the area was approved by the MDP for the second time in 2002.

The main martial purpose in the area was training. The picket in the area was responsible for keeping the area ready for military education. Because the area is in the city center and surroundings are residential, it was used for education on military camps and physical training instead of military drill. Apart from a narrow granite pavement line and surrounding wall, the only constructions in the area are 36 one-story masonry (mainly brick and concrete) buildings. While only three buildings were used as camping storage, one as temporary guardhouse and one as water storage, the other 31 abandoned-looking buildings had no special function except shelter for both the picket and some wild animals including birds and small mammals. Because access to the area had not been permitted for more than 30 years and military activities had always been quiet and nature-friendly, such as camping and physical training, the city suddenly realized that it has a well-protected natural area with significant flora and fauna; thus, the government decided to remove the martial function from the area in 2011, and to open it to the public as a botanical garden.


**Figure 1.** Study Area.

## 2.2. Roofs as Vegetation Habitat

Despite the fact that we were unable to find an official document that addresses when these 37 building were built, it is not difficult to guess it was around the first military declaration in the 1970s when talking with the local people living around the area and examining the buildings' current conditions. Because the MDP 1989 addresses them and this plan is based on the MDP 1978, it is possible to say that they have a history of more than 35 years.

The roofs are concrete and their dimensions vary depending on the forms and the functions of the buildings. Their surface areas are within a range of 2.22–234.6 $m^2$ Although flat roofs are generally found in regions with low precipitation, and the city of Trabzon has a typical climate of the Black Sea region with plentiful precipitation year round, all roofs are flat or slightly sloped, mono-pitched up to 2.27°.

Despite field investigations proving that there has been no artificial interference on the roofs for long years, we preferred to go further, examining the military daily duty records and could not find any cleaning and maintaining activity on the roofs. The interviews with the commandants could also emphasize that the roofs had been left untouched since they were built because either the roofs were properly doing their functions or the army had not been interested in the roofs that much as the buildings had no important functions.

As one of the most important green roof components, and the biggest deficiency when talking about vegetation on a traditional roof, substrate strongly depends on geometry of the roofs and their locations within the area. Even though holding any material is a big challenge for a flat or slightly sloped surface in open area, it is clear nearly all roofs in the area could do this in different amounts. There are basically two different types of roofs in the study area: while the first group possesses only a horizontal surface, those which belong to second group are surrounded with 10 cm raised concrete barrier frames from the roofs' surfaces, which turned the roof surface into a shallow pool to collect substrate material easily (Figure 2a,b). The main materials of the substrate on the roofs are leaves and branches from the trees in the area; sand, soil and dust brought by the wind, fauna and any other natural way; and dead plant matters from the previous years. The roofs in the first group naturally has only a few millimeters to centimeters of substrate because wind, rain and other natural factors can easily remove it from a flat surface just like the way they were brought. However, the second group might hold as much substrate as artificial extensive green roofs have, owing to their more suitable conditions compared to the first ones.

(**a**) (**b**)

**Figure 2.** (**a**) Roof with no barrier; and (**b**) roof surrounded with barrier.

## 2.3. Sampling Procedure

The roofs were evaluated within three basic parameters: ecological, physical and vegetation characteristics. Ecological parameters possess four variables. Because direct sunlight is suggested to be the most important challenge for the vegetation on roofs, daily average direct sunlight period and the area getting the sunlight were recorded for each roof. To eliminate the gap fraction, each roof was divided into $50 \times 50$ cm$^2$ grids and each grid taking direct sunlight with the rate of >50% on its surface were accepted as "it takes direct sunlight" by ignoring the grid's smaller part. In the end, number of the grids taking direct sunlight was used to calculate the percentage for each roof. One of the other important components for roof vegetation, substrates were also analyzed because its depth and pH were considered as crucial, even though it was clear that there was no significant difference among the substrates on the roofs in the area after the studies in the soil ecology laboratory in Faculty of Forestry in KTU. As for physical parameters, location, altitude and height were recorded as the basic things to identify the roofs' positions in the research area. Dimensions were also recorded as the size of a habitat might be used to explain its ecological value. Two other important variables that directly affect existence of substrate on the roofs, inclination and barrier frames, were also added to the physical parameters. Finally, when focusing on the roof vegetation, whole surface of each roof was carefully examined, as they were already smaller when compared to many natural areas that vegetation studies were done and every plant species that we found on the roofs was collected during a year-round intensive field study. All the species that were collected in the research area were identified in the laboratory, using KATO (Herbarium of the Forestry Faculty, Karadeniz Technical University) specimens and some botanical sources [24]. Taxa names given in this study conform to those of [25,26]. Then, species richness, composition typologies and the area covered with the vegetation on the roofs were evaluated.

In addition to plant species presence and abundance at different green roof microhabitats, basic roof parameters including ecological and physical characteristics were also recorded (Table 1).

**Table 1.** Set of basic parameters used for the characterization of the roofs.

| Basic Roof Parameters | Variables | Description/Unit | Assessment Method |
|---|---|---|---|
| Ecological | Daily average direct sunlight period (DADSP) | Hour (0 < 2 < 4 < 6 < 8 < 10+) | Stopwatch/Measured on site |
| | Direct sunlight area on the roofs | Percentage | Measured on site/Office work |
| | Tree species over the roofs | Species | Identified using KATO |
| | Substrate characteristics | Material | Analyze in ecology laboratory |
| | Substrate depth | Average/cm | Measured on site |
| Physical | Location | Coordinate (Urban, Sub-urban) | GPS/Map/Measured on site |
| | Altitude | Meter | GPS/Measured on site |
| | Aspect | Cardinal directions | GPS/Map/Measured on site |
| | Dimensions | Meter | Laser distance meter/ Measured on site |
| | Height | Meter | Laser distance meter/ Measured on site |
| | Inclination | Gradient | Incline meter/Measured on site |
| | Barrier to hold substrate | Yes, No | Observation/Visual assessment |
| Vegetation | Species richness | Number of species on the roofs | Measured on site/KATO |
| | Composition typology | Type | Measured on site/Visual assessment/Office work |
| | Vegetation cover on the roofs | Percentage | Measured on site/Office work |

## *2.4. Data Analysis*

Despite the fact that we collected so many data in the research area, some variables were removed to tackle the problem of collinearity when a pair of variables was highly correlated and to create more compact database when those variables were not able to express significant differences in the research area. For instance, tree species over the roofs were ignored as they were basically and homogeneously *Quercus rubra*, *Fagus orientalis* and *Robinia pseudoacacia*. Similarly, and probably because of that, as trees were supposed to be one of the main material sources for the substrates on the roofs, substrate characteristics were ignored because no difference among the substrate on the roofs was found after the analysis at Karadeniz Technical University. In addition, altitude, aspect and inclination were also removed because no significant difference all over the research area was detected.

In this study, 37 roofs and the vegetation on them were determined. The study examined the relationships between the physical and ecological characteristics of the roofs and their effects on the roof vegetation. Microsoft Office Excel program was initially used to classify all the data we had. Having identified all the vegetation collected on the roofs in the research area, we created tabular data for the further analysis such as life forms, nativeness, families and occurrence.

Data analysis was based on the abundance and presence of various vegetation types and habitat variables all over the roofs in the research area. The correlation coefficient level >0.7 was adopted for strongly correlated variables in this study, similar to Jim at al. [27] did in their wall vegetation research. To identify the habitat variables that affect the combinations in vegetation occurrence, multiple regression analysis was performed using SPSS 23 licensed by Karadeniz Technical University.

## 3. Research Findings

Urban areas are important as they are home to many different fauna and flora, and of course humans that they have to live together. Therefore, even densely settled environments contain elements of biodiversity that deserve the attention of conservationists [28]. There is no doubt that the most interesting part of this study is the research area itself. Despite the fact that nearly every part of Trabzon is under real housing pressure because the city is hilly and population is growing, similar to many other cities all over the world, this study aims to help find an answer to a very popular and provocative question, "What if humans disappeared in urban areas?", by examining the vegetation of 37 roofs in an urban core area that had had no public access for more than 30 years.

As for nativeness, 29 species (52.94%) out of 51 are known to be native in Trabzon, while the rest (22 species out of 51 47.06%) seem to be introduced to the city (Figure 3). There might be a few ways to explain why these non-native species can be found in the study area. First, being a former military area, it had already been in service to many eminent soldiers that are known for their interest in ornamental plants in the country for long years. Therefore, they can be defined as "escapees from the near environment", because, especially landscapes of administration buildings in military areas, are some of the best cared for areas in Turkey. The roof vegetation in the research area has 51 species in 30 families.

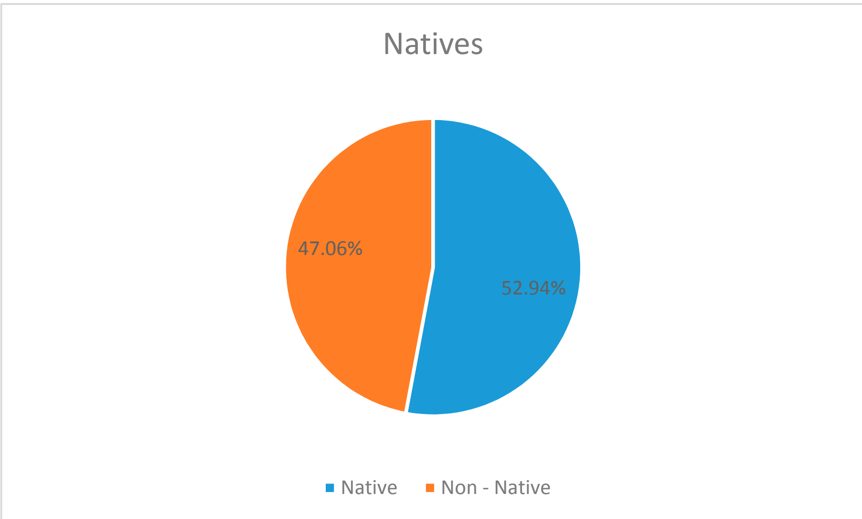



**Figure 3.** Nativeness of the plant species found on the roofs.

The basic wall parameters mentioned above and some others that were added after identifying the plant species such as life forms classification by Raunkiaer (Table 2) [29].

**Table 2.** Raunkiaer life form classification system [29].

| Life Form | Location of Parent Tissue | Plant Types |
|---|---|---|
| Phanerophyt | >0.5 m | Trees and tall shrubs |
| Chamaephyt | 0–0.5 m | Small shrubs and herbs |
| Hemicryptophyt | Soil surface | Prostrate shrubs or herbaceous plants that dieback each year |
| Crytophyt (Geophyte with rhizome) | In the soil | Rhizomatous grasses |
| Crytophyt (Geophyte with bulb) | In the soil | Bulb forming herbs |
| Therophyt | Seed | Annuals |

As for life forms, it also varies in the research area. We found six different life forms: out of 51 species, 28 species (54.9%) are hemicrophyt; 10 species (19.61%) are phanerophyt; seven species (13.73%) are cryptophyt (geophyt with rhizome); four species (7.84%) are chamaephyt; one species (1.96%) is crytophyt (geophyt with bulb); and one species (1.96%) is therophyt (Figure 4).

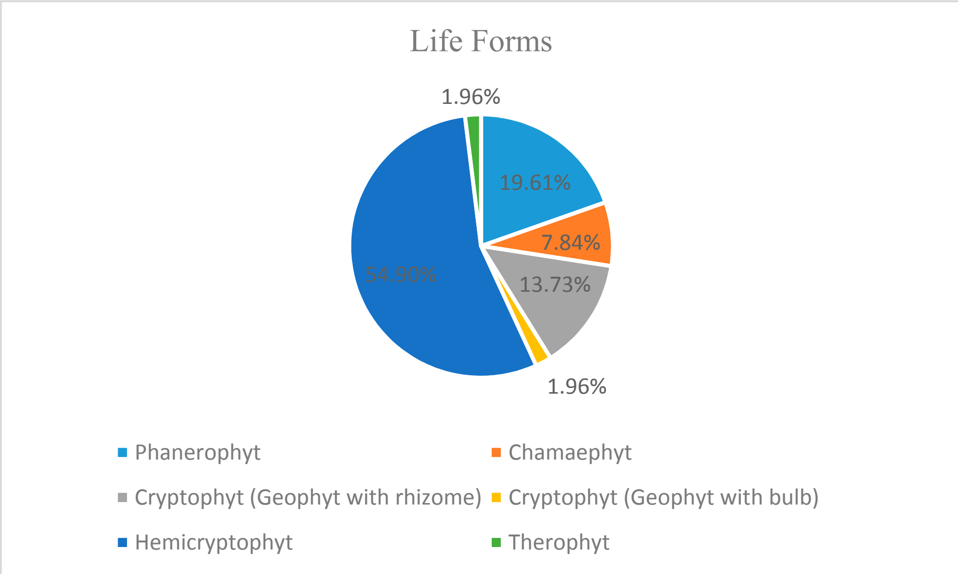



**Figure 4.** Life forms of the plant species found on the roofs.

While all vegetation characteristics are important, we also focused on the vegetation composition typologies because it would be a great contribution to the natural green roof models that artificial green roofs should not only be ecology important but also be visually valuable. In the research area, we found five different natural green roof typologies. While type B that has only herbs is the most common green roof type (13 roofs, 35.1%), we found that type D that has taller herbs and woody plants (10 roofs, 27%), type E that herbs, climbers and woody plants (six roofs, 16.2%), type C that has only *Hedera helix* (five roofs, 13.5%) and type A that has only moss (three roofs, 8.1%) are the other natural green roof typed in the research area (Table 2).

## 4. Result and Discussions

### *4.1. Component Analysis of Green Roof Habitat Attributes*

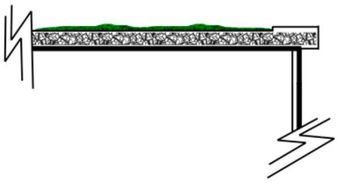
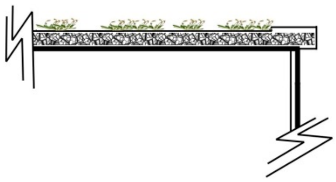
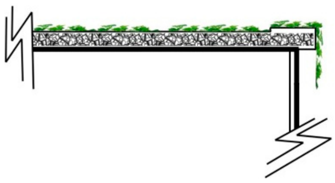
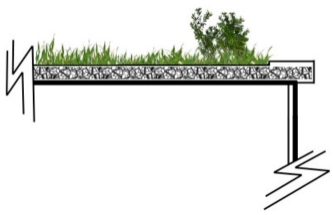
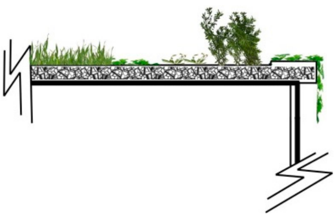
Because the main goal in any artificial green roof is to cover roof surfaces with vegetation and success is considered a perfect coverage rate, we first wanted to see which habitat attributes affect coverage (Table 3).

Even though Jim at al. [30] underlined that larger habitats do not have more trees or more species in his wall vegetation research, while roofs and walls were accepted as similar habitats in many researches, we found that larger roof surfaces have larger vegetation coverage in the research area. This might be because larger habitats have more stable ecological conditions that many species might require, or because microhabitat conditions on the roofs might easily vary to attract more plants. However, Steinbauer at al. [31] reported, in contrast to their expectations, larger irregularities are associated with low species numbers.

We found that species richness on the roofs positively affects vegetation coverage on the roofs in the research area, while it is quite possible to see one dominant species might cover nearly all the habitat in which they exist in natural environments. We believe this is an important reference, while the world of artificial green roofs is likely to be left to a few dominant genera such as *Sedums*, from which we found only one species at a low frequency in the research area, *Sedum hispanicum* var. *hispanicum.*

Apart from their ecological benefits to urban environment, artificial green roofs are known to be useful tools to control air-condition of buildings, especially against solar radiation heat. At that point, we should accept the fact that the natural green roofs in the research area are a bit different from their artificial samples; while the main challenge for vegetation on artificial green roofs is already this solar radiation, it is still surprising to see that size of the parts taking sunlight on the roofs and the sunlight duration on the roofs positively affect vegetation coverage on the roofs in the research area. This is an important finding when considering urban roof vegetation as more sustainable alternative to mainly exotic species of artificial green roofs.

**Table 3.** Green roof typologies.

| Natural Green Roof Type | Main Species (Surface > 10% for Each Roof) | Habitat |
|---|---|---|
|  Only moss (**Type A**) | - *Bryophyta* sp. | - No or very limited substrate<br>- Little or no sunlight area on roof |
|  Only herbs (**Type B**) | - *Geranium purpureum*<br>- *Oxalis corniculata*<br>- *Conyza canadensis*<br>- *Taraxacum buttleri* | - Limited or relatively thick substrate<br>- Moderate sunlight area on roof<br>- Limited sunlight period during the day |
|  Only climbers (**Type C**) | - *Hedera helix* | - No substrate<br>- Limited sunlight area on roof<br>- Limited sunlight period during the day |
|  Taller herbs and woody plants (**Type D**) | - *Robinia pseudoacacia*<br>- *Corylus avellana*<br>- *Solanum nigrum*<br>- *Stipa bromoides*<br>- *Oxalis corniculata*<br>- *Bryophyta* sp. | - Moderate to thick substrate<br>- Relatively bigger sunlight area on roof<br>- Relatively longer sunlight period during the day |
|  Herbs, climbers and woody plants (**Type E**) | - *Rubus canescens*<br>- *Robinia pseudoacacia*<br>- *Ficus carica*<br>- *Hedera helix*<br>- *Geranium purpureum*<br>- *Oxalis corniculata*<br>- *Bryophyta* sp. | - Moderate to thick substrate<br>- Bigger sunlight area on roof<br>- Longer sunlight period during the day |

Artificial green roofs are generally well organized habitats so that vegetation on them can easily survive and grow as customers already pay for it. However, when talking about natural roof vegetation, the conditions are a bit far from the ideal and nature has to find a way to create "magic". Substrate, on which the roof vegetation strongly depends to take water and nutrients, is one the most important parts of this magic. We detected no difference among the substrate on the roofs in the research area, although the depths varied. While wind and gravity can collect some substrate on the roofs, precipitation and wind associated with other weather conditions could accelerate its removal as well. In any condition, substrate is essential for the roof vegetation. This is proven by the finding that depth of the substrate positively affects vegetation coverage on the roofs in the research area, which means the roof vegetation that naturally have a great difficulty in finding substrate to grow covers better when it finds deeper substrate, owing to roof geometry, location and natural conditions.

In this study, multiple regression analysis was performed to examine which habitat factors affect vegetation coverage on the roofs most, and whether these independent variables can be used to explain vegetation coverage on the roofs (Table 4).

**Table 4.** Correlate analysis for study area.

| Correlations | | | | | | |
|---|---|---|---|---|---|---|
| | | **Roof Space** | **Substrate Depth** | **Species Richness** | **DADSP** | **Direct Sunlight Area on the Roofs** |
| Vegetation Cover on the Roofs | Pearson Correlation | 0.708 ** | 0.741 ** | 0.774 ** | 0.713 ** | 0.603 ** |
| | Sig. (2-tailed) | 0 | 0 | 0 | 0 | 0 |
| | N | 37 | 37 | 37 | 37 | 37 |

** Correlation is significant at the 0.01 level (2-tailed).

While we found no relation at the significance level of 0.05, and this meant none of the independent variables could explain plant coverage on the rooftops by itself, substrate depth still seemed the strongest variable compared to roof area, species richness, daily sunlight duration and size of the part taking sunlight (Tables 5–7).

**Table 5.** Model summary for study area.

| Model Summary | | | | |
|---|---|---|---|---|
| **Model** | **R** | **R Square** | **Adjusted R Square** | **Std. Error of the Estimate** |
| 1 | 0.563 [a] | 0.317 | 0.207 | 0.896 |

[a] Predictors: (Constant), substrate depth, species richness, DADSP, Direct sunlight area on the roofs, roof space.

**Table 6.** ANOVA [b] test for study area.

| ANOVA [b] | | | | | | |
|---|---|---|---|---|---|---|
| **Model** | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| 1 | Regression | 11.551 | 5 | 2.310 | 2.878 | 0.030 [a] |
| | Residual | 24.881 | 31 | 0.803 | | |
| | Total | 36.432 | 36 | | | |

[a] Predictors: (Constant), substrate depth, species richness, DADSP, Direct sunlight area on the roofs, roof space.
[b] Depend variable: Vegetation cover on the roofs.

**Table 7.** Regression analysis for study area.

| Coefficients [a] | | | | | | |
|---|---|---|---|---|---|---|
| **Model** | | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | | **B** | **Std. Error** | **Beta** | | |
| 1 | (Constant) | 3.831 | 0.526 | | 7.289 | 0.000 |
| | Substrate Depth | 0.514 | 0.230 | 0.450 | 2.233 | 0.033 |
| | Species Richness | −0.729 | 0.274 | −0.561 | −2.662 | 0.012 |
| | DADSP | 0.079 | 0.230 | 0.100 | 0.342 | 0.734 |
| | Direct sunlight area on the Roofs | −0.265 | 0.177 | −0.416 | −1.498 | 0.144 |
| | Roof Space | 0.277 | 0.305 | 0.178 | 0.910 | 0.370 |

[a] Dependent Variable: Vegetation Cover on the Roofs.

*4.2. Roof Vegetation as Reference to Artificial Green Roofs*

Despite the fact that artificial green roofs are scientifically proven to be economical in long term by many studies, cost of investment is still one of the most important and effective obstacles to their prevalence. Therefore, understanding roof vegetation dynamics that causes natural, free green roofs might be essential to make artificial green roofs more common and to create ecologically more sustainable cities.

Normally, rooftop conditions are not considered ideal habitats for plants. Moisture stress and severe drought, extreme high temperatures, high light intensities and high wind speeds increase the risk of desiccation and physical damage to vegetation and substrate [1]. Because spontaneous roof vegetation already has adaptations that enable them to survive in these conditions, they can easily be used to create sustainable extensive green roof solutions that require less maintenance. As with the most important reason that roof vegetation is critical for artificial green roofs, green roof communities are dynamic, and, with time, vegetation is likely to change from the original composition [19]. Because natural roof vegetation is already stable or partly stable as a result of the dynamic process that Köhler [19] mentioned, it would be logical to evaluate its characteristics to establish an artificial green roof.

Even if many species were tested in different rooftop conditions [23,32,33], *Sedum* species outperformed the other taxa, except in consistently moist substrate deeper than 10 cm, in which taller plants canopy layer created shaded conditions that proved unfavorable to the *Sedum* species [3].

However, even though there was only one rooftop out of 37 having substrate layer deeper than 10 cm in the research area, *Sedum* was still far from being a common roof vegetation member with the rate of 3/37 among the rooftops. This is probably because the rooftops had already a tree canopy over the research area. However, it is still interesting that such superstars of green roof world, *Sedum* species, were found only on three rooftops while just seven out of 37 rooftops could not take sunlight directly in the research area. Furthermore, some *Sedum* species are known to grow in substrate layers as thin as 2–3 cm [34], while more than half of the rooftops in the research area already have substrate layers under 3 cm. Because we expected to find more *Sedum* species on more rooftops under the light of previous roof vegetation and green roof studies before we started this research, it might be time to talk about some new species for rooftops. We know that this is not a fresh approach and, in theory, nearly any plant taxon can be used on rooftops, assuming it is suited to the ecological and physical conditions of the location. However, many scientific studies report native species fail as green roof plant. Even though many native species appear to be unsuitable for conventional extensive green roof systems because of the roofs' harsh environmental conditions and typically shallow substrate depths [3], and, according to a study at Michigan State University, only four of the original 18 native prairie perennial species growing in 10 cm of substrate persisted after three years [23], we found that 57.38% of all the plant species on the rooftops in the research area is native. As a result, because policies for sustainability support the establishment of locally representative plant communities, native plants' potential for green roofs should never be ignored in scientific studies, as we found that they can spontaneously grow on rooftops and can be dominant against supposed green roof plants.

In the real world, time, money and getting the ideal results in a short period are essential. Landscape designers who do not want to risk their success might want to use a few hardy and possibly cheaper plant species in their planting designs. When talking about green roofs, the situation is not that different. While *Sedum* has remained the most commonly used genus for green roofs for a long time, according to our finding, using a wider scope for green roof vegetation would be a more logical, as it is clear that, the more species grown on rooftops, the more vegetation coverage might naturally be seen there.

Although green roofs were born to contribute to sustainability, both economically and ecologically, today it is possible to see that they are partly turned into a PR object by many companies, shopping centers and contractors. However, if any investor or employer has to pay more than they can save, owing to energy conservation, or if green roofs can cause some ecological problems, such as genetic pollution by using invasive or exotic species just because they can survive in roofs' hard ecological conditions, then it is time to think about why we are trying to have roofs covered with plants. Because green roofs should be sustainable, natural roof vegetation should be the best teacher to learn how things can be organized in harmony with ecological conditions on rooftops.

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