Evaluating the Potential for Green Roof Retrofit in Urban Fabric

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Abstract: Green roof benefits include: *urban heat-island reduction, mitigating air pollution, reducing rainwater runoff and increasing urban biodiversity*. In addition green roofs have aesthetic benefits, and can be an excellent medium for urban agriculture. This paper suggests a method to evaluate the potential for green roof retrofit on a large urban fabric. GIS based analysis methodology was established and applied to the city of Netanya, Israel. Based on the analysis 0.85 km^2 (1,214 buildings, 9 % of total buildings) was found to be suitable for an intensive green roof system, and 0.92 km^2 (3,004 buildings, 22 % of total buildings) was found to be suitable for an extensive green roof system.

Keywords: Geodesign, simulation, green roof

1 Introduction

The world is becoming denser, as the population continues to grow; the need for housing increases. Israel is no exception, According to the Central-bureau-of-statistics, by the year 2059 Israel population would double (CENTRAL BUREAU OF STATISTICS 2012). As the need for housing increases, more and more green areas are being replaced by residential housing. More than 50 % of Israel's population currently resides in urban areas. With the expansion of the urban fabric, the environmental impacts increase. Various studies have demonstrated that implementation of green roofs in urban areas, can help mitigate some of the environmental impacts associated with urban settlements: *Urban heat reduction, storm water runoff mitigation and reducing air pollution* are some of the environmental benefits associated with the implementation of green roofs in urban areas.

As a direct result of the Mediterranean climate in Israel, most of the structures have a flat roof. Making Israel especially compatible for a wide spread implementation of green roofs. Green roof retrofit is possible if the structure has: *sufficient load bearing capability, proper sealing coverage, and a slope with pitch of no more than 30°*. To ensure that a structure has a sufficient load bearing capability, the structure must be evaluated by a structural engineer. The Israeli building standard no.412 determines the minimal load bearing requirement for each structure type. Residential structures are required to withstand 150 kg/m^2, commercial structures 400-500 kg/m^2 and industrial structures between 500-750 kg/m^2. The type of green roof that can be retrofitted, depends on the load bearing capability of the structure. Extensive green roofs are lighter, with soil depth varying from 5 cm to 20 cm. The maximum load in an extensive roof system is 225 kg/m^2. Intensive roof system is more demanding with soil depth varying from 20 cm to 150 cm. The maximum load of an intensive green roof system depends on the depth of the soil and vegetation type*. An intensive green roof can weigh up to 2000 kg/m^2 (Table 1). Lightweight-substrate materials such as pumice and extended clay, can be used to construct a semi-intensive green roof (depth up to 40 cm), with loads similar to an extensive green roof (WILKINSON & DIXON 2016).

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Table 1: Extensive and intensive soil based green roof loads (*Saturated soil) (WILKINSON & DIXON 2016)

Vegetation	Depth(mm)	Weight Kg/m²
Extensive green roof with sedum, grass, moss, etc.	50-100	10 70-140*
Extensive green roof with soil, plants and small shrubs (Below 0.5 m)	100-150	15 140-225*
Intensive green roof with larger plants and small shrubs (Below 1 m)	150-200	20 225-300*
Intensive green roof with larger plants and small shrubs (Below 3 m)	200-400	30 300-600*
Intensive green roof with larger plants and small trees (Below 6 m)	400-1000	60 600-1500 up to 2600
Intensive green roof with larger plants and small trees (Below 10 m); one tree weighs more than 150 kg	Over 1000	150 when one tree is 1000 kg/m²

A recent study suggested a GIS based mapping methodology of urban green roof ecosystem services. The study was conducted on Braunschweig, located in Northern Germany. The study used a digital elevation model from airborne laser scanning, to calculate roof slopes and identify obstructions. Structures with slopes larger than 5◦ were excluded from the calculation. The remaining structures with an unobstructed roof area greater than 75 % were classified as appropriate for a green roof system, while structures smaller than 75 % were classified as limited appropriate. *Land use, traffic intensity and a building ground plan data* was used to rate the benefit of the urban ecosystem services across Braunschweig. The study concluded that 8596 (8.6 % of total number of building) were appropriate for green roofs, out of those 867 were categorized as high benefit, 3550 as moderate benefit and 4179 as low benefit (GRUNWALD et al. 2017).

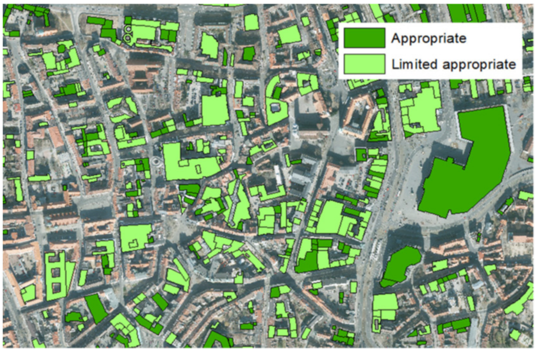

Fig. 1: Green roofs potential area in the city center of Braunschweig (GRUNWALD et al. 2017)

2 Evaluating the Potential for Green Roof Retrofit

2.1 Study Area

Netanya is a coastal city located north of Tel-Aviv, in the center of Israel (lat-32.321457, long-34.853195). Netanya has a population of 207,946, in an area of 34.7 km^2. The buildings take a total plan area of 3.6 km^2 (Figure 2). The study was performed using data extracted from the municipal GIS system (developed by Taldor). For this research the following data was used:

1) Topographical information.
2) Building information (height, floor-plan, number of floors, building type and year of construction).
3) Orthographic aerial photographs.

The data was analysed using Grasshopper (a plug-in for Rhinoceros 3d modelling software). The evaluation was performed using two levels of analysis. First the possible potential for green roof retrofit on a city scale, second the potential for green roofs retrofit in localized urban fabrics.

Fig. 2:
Netanya – All structures

2.2 City Scale Evaluation

In the city scale evaluation, the algorithm reviewed all of the structures in the city; 13,624 in total. The structures were classified as: *suitable for intensive green roof, suitable for extensive green roof and not suitable*. Using the available GIS data, structures dated before 1970 were classified as not suitable, based on the assumption that structures dated before 1970, are not suitable for the load bearing requirements for green roof retrofit. The remaining structures were classified by analysing aerial photographs; for each structure typology and type (Figure 3-6).

Fig. 3: Residential structure with two floors

Fig. 4: Residential structures with three to ten floors

Fig. 5: Residential structures above ten floors

Fig. 6: Industrial structures

Residential structures up to two floors usually had a sloped roof. Although sloped roofs with pitch under 30° can be suitable for green roof retrofit (WILKINSON & DIXON 2016), data on the pitch for each roof was not available. Therefore, those structures could not be evaluated, and were classified as not suitable. Residential structures from three to ten floors, usually had a flat roof with 50 % of the area obstructed by solar heating systems. Those structures were classified as suitable for an extensive green roof system. Residential structures above ten floors, usually had a flat roof with 25 % of the area obstructed by system outlets. Those structures were classified as suitable for an intensive green roof system. Commercial, public, and industrial structures usually had a flat roof with a few system outlets. Those structures were classified as suitable for intensive green roof. Single floor industrial structures were usually hangers with a lightweight roof. Those structures were classified as not suitable. All other types of structures (storage facilities, gas stations, taxi stations, etc.) were classified as not suitable.

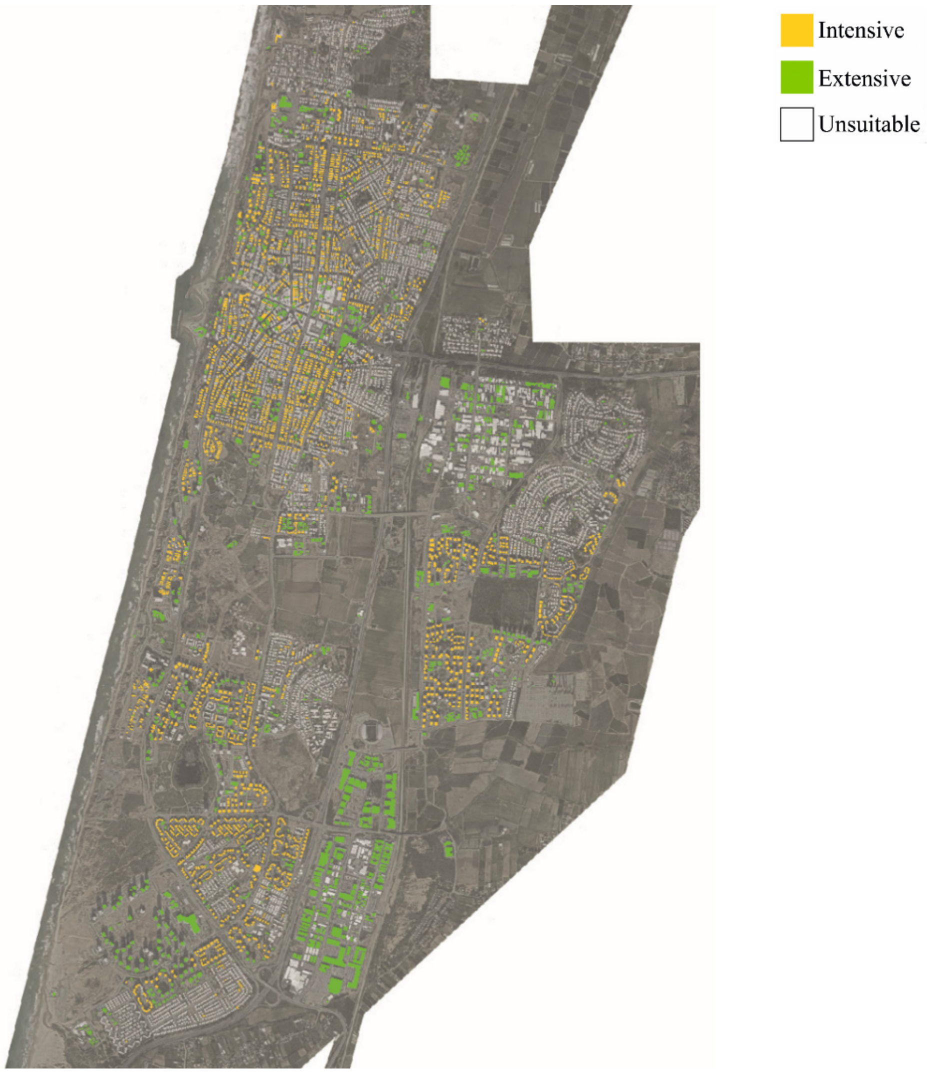

Fig. 7: City scale evaluation for green roof retrofit

2.3 Localized Urban Fabrics Evaluation

In the second level of analysis, different urban fabrics were evaluated further In order to determine the amount of light exposure in each individual roof. A 3D model of each fabric was constructed, using topographical and building data extracted from GIS layers. Sunlight exposure analysis was conducted on all of the roofs in the chosen fabrics. The simulation used the sun vectors on three days: *the 21st of December, 21st of March and the 21st of June*. Roofs with an average light exposure of less than 50 % of light hours, were classified as not suitable for a green roof system (Figure 8).

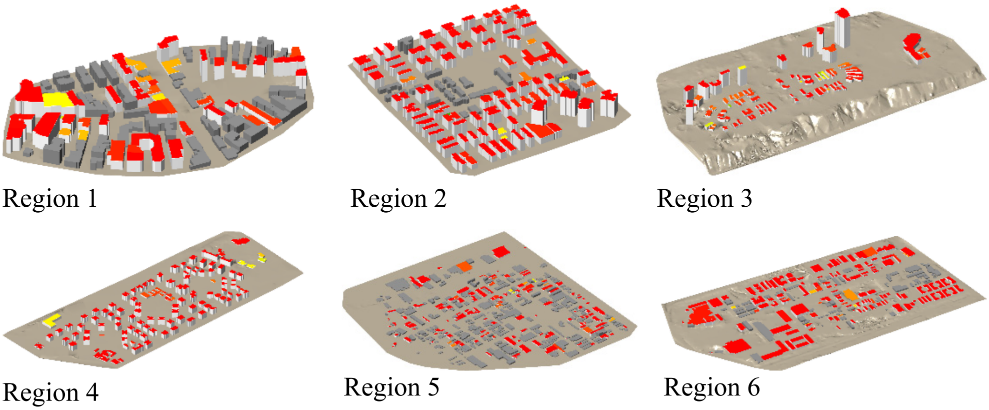

Fig. 8: Solar study on localized urban fabrics: *regions 1-2 city center, regions 3-4 new structures, regions 5-6 industrial areas*

3 Results and Discussion

In the city scale evaluation, a total area of 0.85 km^2 (1,214 buildings, 9 % of total buildings) was found to be suitable for an intensive green roof system. A total area of 0.92 km^2 (3,004 buildings, 22 % of total buildings) was found to be suitable for an extensive green roof system. A total of 1.85 km^2 (9405 buildings, 69 % of total buildings) was found to be unsuitable for a green roof system (Figure 9).

In the localized urban fabrics evaluation, six urban fabric regions were analysed (Figure 10). Regions 1 and 2 are urban fabrics at the city centre. Regions 3 and 4 are new urban fabrics. Regions 6 and 7 are industrial areas. Sunlight exposure evaluation showed that most of the suitable roofs get enough sunlight throughout the year (more than 50 % of total sunlight hours) (Figure 8). Due to the uneven height and high density nature of urban fabrics closer to the center of the city, the average exposure to sunlight was lower than the newer urban fabrics farther from the center of the city. Industrial areas had an even exposure to sunlight.

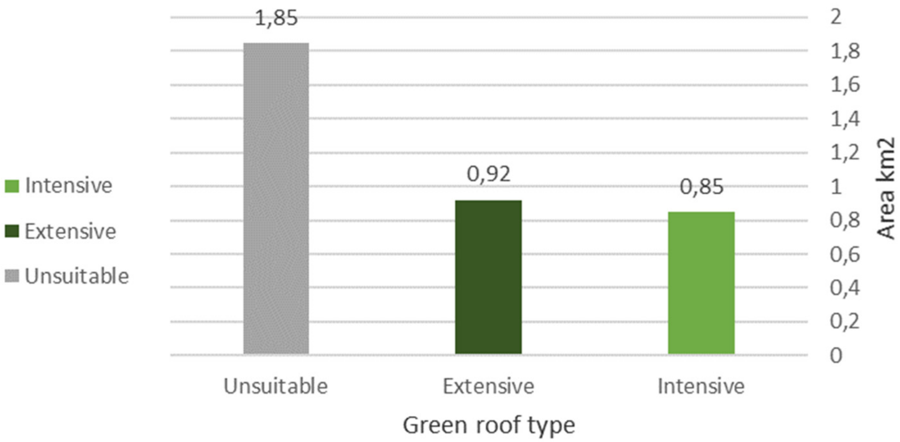

Fig. 9: Green roof potential – city

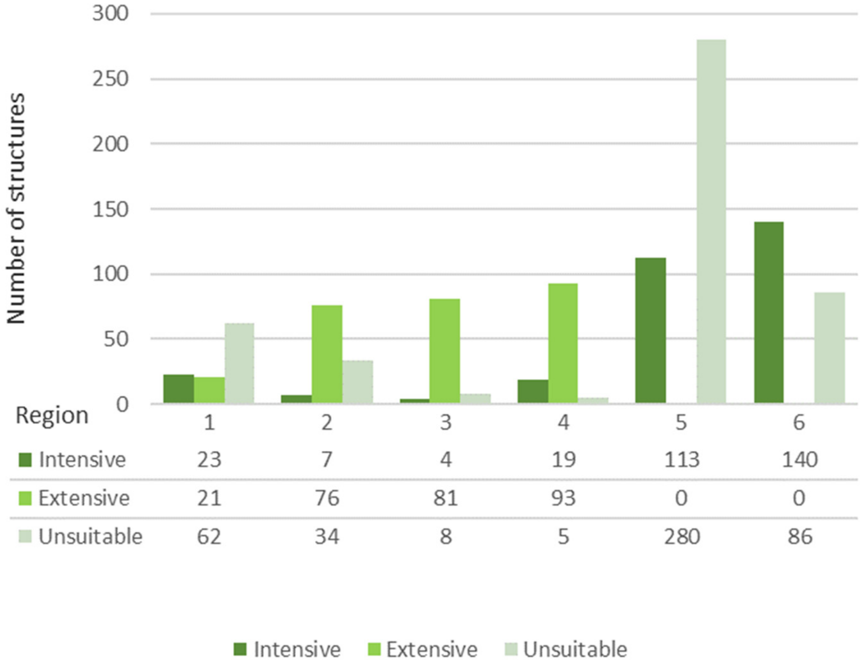

Fig. 10: Green roof potential – regions

This study proposes a method to evaluate the potential for green roof retrofit using GIS analysis tools and the Grasshopper plug-in for Rhinoceros. Due to the limited data that was available for this evaluation, the results are an approximation of the potential for green roof retrofit over a large area. Assumptions were made on structures dated before 1970 and structures with sloped or lightweight roofs. For a more precise evaluation further structural and roof data is needed for each structure. The sunlight hour's evaluation was conducted on flat roof surfaces based on the building floor-plan and in small regions. For an accurate sunlight hour's assessment, elevation data for each roof, and accurate mapping of obstructions is needed. With that being said this paper generates a first estimation of the urban potential for green roof retrofit, with additional data more accurate results can be achieved.

4 Conclusion

This paper presents a GIS based methodology, to evaluate the potential for green roof retrofit on a large urban area. By using GIS data and the Grasshopper plug-in, the potential for green roof retrofit in city of Netanya was evaluated. This paper concludes that Netanya could potentially have 0.85 km^2 of intensive green roof systems and 0.92 km^2 of Extensive green roof systems. With the increasing demand for housing, the addition of 1.77 km^2 of green roofs to the existing city, can greatly reduce of the environmental impacts affecting the urban landscape. As an extension of the municipal GIS. The proposed approach can be used by municipalities and individuals, to assess the potential for green roof retrofit on a scale ranging from the whole city to a single structure.

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