The potential roles of biodiverse green roofs in the extending urban green network

Krisztina Szabó
Szent István University, Faculty of Landscape Architecture and Urbanism, Department of Garden and Open Space Design

Introduction

The role of urban green network is increasingly needed due to urbanization and the growing urban population. The high number of buildings, the different infrastructural developments and the high quantity of covered surface do not allow increase greenery on the ground level; there are few residual spaces that can be turned into green areas. One solution could be the vertical walls and green roofs which can considerably help developing urban green network of the future (Susca et al., 2011). Due to the acute conflicts between high density development and limited land, many European, American and Chinese cities adopted an effective way to increase green space in high-rise building areas, such as roof gardens, wall, vertical, balcony and windowsill greening (Li et al., 2004). The range of benefits was set out in many researchers (e.g., Johnston and Newton, 1993; Wong et al., 2003; Gregoire and Clausen, 2011).

In Hungary the first green roof was built in 1991. Even since then, complex studies on green roofs have not been conducted with long-term monitoring and scientific statistical evaluation of the vegetation, substrates etc. In 2016 a PhD study was made on extensive experimental green roofs (Szőke, 2016), but it only superficially deal with biodiverse green roofs as a type of extensive green roofs, the aim of said study was not the biodiversity of green roofs. Moreover, no data is available on the number and extension of these kinds of roofs. Only a few attempts were made to organize and register green roofs in the past two decades (Szabó, 2010; Szőke et al., 2013). The number of biodiverse green roofs is low (half a dozen).

Literature Review

The plant application in urban domains becomes more difficult because of climate change. This fact was revealed and confirmed by independent studies based on analysis of climatic data of the last two hundred years (Mika, 1997). In consequence, even if it is to a lesser degree, Hungary will be dominated by a mostly Mediterranean climate. In Hungary, an unambiguous change in the climatic effects tendency of temperature can be observed, and the average correlates well with the global tendencies or it could be even higher. The precipitation index of summer (-10 – -33%) and autumn (0 – -10%) will decrease (Bartholy and Pongrácz 2008). The negative effects of the global tendencies are increasingly expressed in cities. According to certain forecasts the impacts of global climate change lead to intensity, expansion, duration and frequency of these negative urban climate phenomena (urban heat island (UHI), dust dome, growing air pollution and airborne dust concentration, decreased transpiration, hectic climatic conditions etc.) in a great number of the cities in the temperate zone, including our homeland. Planning and selection of correct plant species is crucial to maintain not natural, liveable circumstances in the future. The application of plant species of adequate can help decreasing the frequency and quantity of irrigation so the same result could be achieved by afforestation and planting on the ground level (Szabó and Bede-Fazekas, 2012) and on the green roofs as well.

The effect of urban built-up density and the land cover types were examined from the viewpoint of the radiated temperature (Oláh, 2012) and in the research methods which can increase the UHI effect were separated and identified. According to Oláh (2012) it can be declared that even a single large-sized building can have a remarkable impact on the urban surface temperature distribution. In the case of such buildings it is not the land use classification, but the thermal qualities of the surface material and the building size which were primarily determinant. A 12 °C difference between the biologically active surface/green roof and other artificial covered roof could occur.

According to Oke (1982) there are two main participants in forming of urban climate, one is the Urban Boundary Layer (UBL, from the roof level to atmospheric) and the other the Urban Canopy Layer (UCL, from the ground level to roof level). The biologically active surfaces in urban domain can reduce the negative effects of urbanization significantly.

The main goals of establishing green roofs vary in different countries, for example utilizing rainwater in Germany, increasing biodiversity in England, reducing UHI in USA, improving air pollution in China (Grant, 2006; Hammerle, 2009; Lawlor et al., 2006), but no such goal was set in Hungary (Szőke, 2016).

Green roofs can be categorized as intensive (organic substance height min. 25 cm, (OTÉK: 40 cm)), or extensive (organic substance height 2-15 cm (OTÉK: 8-20 cm)), depending on the depth of planting medium and the amount of maintenance they need. Some researchers define transitional form, semi-intensive (organic substance height 10-25 cm (OTÉK: 20-40 cm)) as well (Hidy et al., 2011). In the last few years biodiverse green roof and extensive green roof have been differentiated (Table 1). In Hungary 134.251 m^2 (33, 9% from total 395.678, 6 m^2) extensive green roofs were built (Szőke, 2016).

The biodiverse green roof respects the theory of biodiversity. In forming and maintenance it provides optimal long-term conditions for diversity of plants and animals. The main physical and structural characteristics are the vertical and hilly surface, the heterogeneous substrates spreading, and substance patches (gravelled, broken stoned, sandy). The different applied plant species form dynamically changing patches. The size of such patches is bigger than 50% of the total area. The vegetation consists of herbaceous perennial in containers and mixed seeds (including annual plants as well). The irrigation is done manually with sprinkle system in some cases a drip-irrigation system is applied. The main goal is to apply irrigation system only temporarily (e.g. for a year), and after that no additional irrigation should be applied. On the biodiverse green roofs there are special structures for insects, so-called bee hotels, which enable the insects to overwinter and provide a place for hiding and reproducing. In parallel with development of the flora, microbiology of the soil (substrate) and fauna will begin to develop (Dunnett and Kingsbury, 2008; Balogh et al., 2013).

The ecology attitude is very important in case of newly created green roofs. The application of native plant species has numerous advantages, as they naturally help to re-establish a healthy ecosystem, and they can adapt to the local conditions and these plants are in-line with local animal species as well (Clark and MacArthur, 2007). Finally, the biodiversity preserving role of native plants could be communicated to locals, thus an ecological way of thinking can be spread on society level (Maclvor és Lundholm, 2011).

However there are some research studies in which the survival rate of native and non-native plants were examined. Based on the results non-native plants had a better long-term survival capacity than the endemic species (Butler et al., 2012; Monterusso et al., 2005). The non-native plants could adapt to extensive conditions much better.

Goals and objectives

The aim of this work is to examine the applicability of biodiverse green roofs in Hungary, and to see how green roofs could be adapted to Hungarian urban green network supported the basic criterions of biodiversity. Furthermore another similarly important aim is to identify planning aspects from the building contractor, everyday user and maintainer points of view.

To achieve my aim I examined the first biodiverse green roof of Hungary, in the Skanska Green House office building, where there are green infrastructural elements, vertical walls, intensive, extensive and biodiverse green roofs as well (Birtalan and Tornóczky, 2014).

The first Hungarian biodiverse green roof

The Green House biodiverse green roof is 1076 m2 which is around a U shaped building on the top floor. In this area 18 breeding spots were created and by using corten steel, therefore a higher planting and breeding layer was formed.

The average height of the substrate was 10-15 cm, with an approximately 55% water retaining capacity (Mrekva and Horváthné, 2008). The characteristics of the substrates are good physical structure, water-holding capacity, water permeability, relative high organic material content, low weight, near neutral pH, and sterility (Dezsényi, 2012).

The planning aspects can be different from the point of view of building contractors, everyday users and maintainers. The planners, Hungarian, Swiss, English and Austrian experts and researchers planned an extensive biodiverse green roof with low maintenance. Originally the plan was to use the irrigation system in the breeding spots (Fig. 1) only in the first year if possible also in the meantime in any other parts of the roof only supplementary irrigation should be applied but strictly in the first year. There was not any rain sensors planted on the roof. The supplementary watering consisted of sprinklers placed in 30 cm height, however later in spite of continuous watering; dry spots and interspaces were observed because the sprinklers were too far from each other. Moreover the low water pressure and the higher plants caused further problems. The plants growing on the dry patches could not develop suitably. Plant mixtures were applied, for example herbaceous plants were combined with woody or suffrutex species (Fig. 1). Moreover some of the plants were planted from seedling and others from seed. The seed mix was Optigreen seed type E (Fogarasi, 2015). There were 64 species with dry habitat preference, e.g. ornamental plants (e.g. *Alyssum montanum 'Berggold'*), such as height solitaires (e.g. *Gaura lindheimeri*), grasses (*Festuca glauca*), and wild species. Other species (weeds) appeared in the second years after planting. Among the woody plants only *Pinus mugo* was planted in breeding spots. To support of biodiversity some landmarks were placed on the roof such as rocks (Fig. 2) mouldy trunks and bee hotel (Fig. 3).

Table 1. The main characteristics of the types of extensive green roof (according to Hidy et al., 1995, Balogh et al., 2013; Szőke, 2016)

	Extensive	**Biodiverse**
Suitable for	larger projects (more cost effective)	Projects with specific biodiverse objectives
Maintenance cost	low	in the beginning higher, later low
Maintenance	minimal	minimal
Usage	impassable, ecological protective layer	impassable, ecological protective layer
Built-up height	70-120 mm	70-200 mm
Weight	80-125 kg/m²	90-225 kg/m²
Inclination	0-25°	0-15°
Specification drivers	An ecological protection layer for: air & water quality, lower carbon emissions, storm water attenuation, wildlife habitat, extended membrane life	Diverse plant strategies can: Replicate or enhance the building's pre-development habitat, Attract specific wildlife
Planting	Colourful carpet of planting: hardy succulents, grasses, herbs. Pre-grown mat plug planted or seed system available	Options for non-vegetated brown roofs or planted with native species such as hardy succulents, grasses, herbs, wildflowers, or suffrutex plants
Irrigation	None, unless specified	None, but according to Hidy et al., 1995, Balogh et al., 2013, Szőke, 2016 in the beginning frequent irrigation,
Planting character	mixed or formed homogenous spots	adapted for plant's demands without planning
Organic content in substrate	15-20%	15-20%

The germination rate was low so it can be said that the foreign seed mixture is not suitable under Hungarian climatic conditions; more than 50 % of the seeds did not germinate at all or germinated one year later). Overcoming weeds (e.g. *Populus* and *Acer seedlings, Chenopodium album, Stellaria media*) caused trouble from time to time.

The main difficulty experienced was the conflicts between the daily users and maintainers. Namely, while the plants were getting the accustomed to dry periods without irrigation, big parts of the plant surface become dry. The roof lost its decorative value at all, which was not tolerated by tenants whose the offices were on the top floor, overlooking the garden. Due to their demands the maintainers had to replant the dry spots, and the irrigation system was restarted for permanent operation (thus the original goals were damaged). According to Fogarasi (2015) 47% of the examined plant species can be recommended for planting, such as *Achillea millefolium, Anthemis tinctoria, Gypsophila repens, Silene nutans*.

Due to data it can be stated that the first Hungarian biodiverse green roof cannot work properly as an extensive green roof, as neither the irrigation nor in any other maintenance problems could be solved.

Figure 1. A breeding spot lifted by corten steel with irrigation system and planted *Pinus mugo*

Figure 2. Combined herbaceous plants such as succulents and other drought tolerant perennials

Figure 3. Bee hotel in the biodiverse green roof of Green House (photos: Krisztina Szabó)

Conclusion

Nowadays, most green areas of the cities are isolated. Isolation inhibits the migration of species and individuals in population which can lead to decrease in genetically diversity and biodiversity at the same time; because the gene exchange is out of question between the less viable smaller communities. The green roofs have crucial importance in preventing habitats' fragmentation and increasing living spaces so after all increasing biodiversity. From this aspect the biodiverse type from all green roofs is the most suitable, because the diversity of species and every applied formation and landmarks serve biodiversity. Nowadays, the ecological value of green roofs is considered to be more important than the aesthetical value. This approach is typical in Western Europe and in USA but not yet in Hungary.

There are some studies with useful information about environmentally preferable choices in urban planning, mitigation strategies and for optimizing energy level of buildings (e.g., Saiz et al., 2006; Kosareo and Ries, 2007; Alexandri and Jones, 2008; Wong et al., 2003; Akbari et al., 1992; Susca et al., 2011) Although decision-makers agree on the importance of green areas, in many cases the decisions cannot be implemented due to economic and social reasons (Láng, 2004). This vision is important from of landscape architectural, horticultural and maintenance point of view as well and the participants have to prepare for changing their attitudes in establishing new green areas not only on the ground level. Green roofs have the potential to play a significant part in achieving sustainable conditions and improving the quality of urban life.

In Hungary the currently built biodiverse green roofs can't fill a part their roles in biodiversity and extensity because of maintenance, irrigation and usage, but the way of looking and estimation are important very much. Further experiments are required that the green roofs can have real and long term effect to provide green services and biodiversity.

References

Akbari, H., Davis, S., Dorsano, J., Huang, S., Winert, S. (1992). Cooling Our Communities - *A Guidebook on Tree Planting and Light Colored Surfacing*. US Environmental Protection Agency, Washington, DC. Retrieved May 2010, from. http://escholarship.org/uc/item/98z8p10x#page-242.

Alexandri, E., Jones, P. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Building and Environment* 43, 480e493.

Balogh, P. I., Bede-Fazekas, Á., Dezsényi, P. (2013). Ökologikus növényalkalmazás és biodiverz zöldtető kialakítása a budapesti Green House irodaház tetőkertjénél. *4D Tájépítészeti és Kertművészeti folyóirat* 8 (2) pp. 2-23.

Bartholy, J. and Pongracz R. (2008). Regionális éghajlatváltozás elemzése a Kárpát-medence térségére. - In: Harnos Zs., Csete L. Klímaváltozás: környezet - kockázat - társadalom. *Szaktudás Kiadó Ház*, Budapest

Birtalan O., Tornóczky M. (2014). Mi újság Green House?
http://www.magyarepitestechnika.hu/index.php/2014-5/1890-mi-ujsag-green-house#&panel1-3&panel2-1

Butler, C., Butler, E., Orians, C.M. (2012). Native plant enthusiasm reaches new heights: perceptions, evidence, and the future of green roofs. *Urban Forestry and Urban Greening* 11, 1–10.

Clark, M., MacArthur, S. (2007). In Proceedings from the Fifth Annual International Green Roofs Conference. *Greening Rooftops for Sustainable Communities*, Minneapolis, April 29 to May 30th. Toronto: The Cardinal Group.

Dezsényi P. (2012). Skanska Green House irodaház növénykiültetési koncepció. Budapest

Dunnett, N., Kingsbury, N. (2008). Planting green roofs and living walls. Portland, or: *Timber Press*.

Fogarasi, D. (2015). A Green House biodiverz zöldtető vizsgálata. Diplomadolgozat. BCE, Kertészettudományi Kar, Budapest

Grant G. (2006). Green roofs and facades. IHS BRE Press

Gregoire, B., Clausen, J.C. (2011). Effect of a modular extensive green roof on stormwater runoff and water quality. *Ecological Engineering*, 37, 963–969.

Hammerle, F. (2009). Der Gründachmarkt in Deutschland-Marktspiegel, Analyse, Entwicklung.

Hidy I., Gerzson L., Prekuta J. (2011). A Zöldtető. A városi tetőtáj koronája. *Terc Ker. és Szolg Kft.*

Johnston, J., Newton, J. (1993). Building Green: A guide to using plants on roofs, walls and pavements. *London Ecology Unit*. London (reprinted 2004 by GLA)

Kosareo, L., Ries, R. (2007). Comparative environmental life cycle assessment of green roofs. *Building and Environment* 42, 2606e2613.

Láng, I. (2004). Agrártermelés és Globális környezetvédelem. Bp. Mezőgazda kiadó.

Lawlor, G., Currie, B., Doshl, H., Wleditz, I. (2006). Green roofs, A resource manual for municipal policy makers, Canada Mortgage and Housing Corporation. ISBN 0-662-44084-6.

Li, F., Wang, R., Paulussen, J., Liu, X. (2004). Comprehensive concept planning of urban greening based on ecological principles: a case study in Beijing, China. *Landscape and Urban Planning,* 72 (2005) 325–336. doi:10.1016/j.landurbplan.2004.04.002

Maclvor, J.S., Lundholm, J. (2011). Performance evaluation of native plants suited to extensive green roof conditions in a maritime climate. *Ecol. Eng*. 37, 407–417.

Magyar, M. (1998). A magyarországi zöldtetők nyilvántartási rendszere FIR alkalmazásával. Gödöllő, Szent István Egyetem, Környezet– és Tájgazdálkodási Intézet, Területi Tervezési és Térinformatikai Tanszék.

Mika J. (1997). Klímaváltozás: hazai sajátosságok, ökológiai követelmények. In: Szász Gábor, Tőkei László. Meteorológia mezőgazdáknak, kertészeknek, erdészeknek. Mezőgazda Kiadó, Budapest

Monterusso, M.A., Rowe, D.B., Rugh, C.L. (2005). Establishment and persistence of Sedum spp. and native taxa for green roof applications. *HortScience* 40, 391–396.

Mrekva L., Horváthné P. J. Zöldtetővel a városi árvizek ellen. http://www2.vizeink.hu/files/vizeink.hu_0616_ZEOSZ_velemenye.pdf 2016.02.29.

Oke, T.R. (1982). The energetic basis of the urban heat island. *Quarterly Journal* of the Royal Meteorological Society, 108, 1-24.

Oláh, A.B. (2012). A városi beépítettség és a felszíntípusok hatása a kisugárzási hőmérsékletre. PhD dissertation. BCE. Budapest

Saiz, S., Kennedy, C., Brass, B., Pressnail, K. (2006). Comparative life cycle assessment of standard and green roof. *Environmental Science and Technology* 40, 4312e4316.

Susca, T., Gaffin, S.R., Dell'Osso, G.R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental pollution*, 159, 2119-2126. doi:10.1016/j.envpol.201103.007

Szabó, K., Bede-Fazekas, Á. (2012). A forgalomban lévő fásszárú dísznövénytaxonok szárazságtűrésének értékelése a klímaváltozás tükrében. *Kertgazdaság*.

Szabó, L. (2010). A zöldtetők szerepe a városok életében. A zöldtetőépítés hazai kilátásainak vizsgálata Budapest példáján. XII. Országos Felsőoktatási Környezettudományi Diákkonferencia Sopron, 2010. TDK dolgozat. 1-48.

Szőke, A. (2016). Extenzív zöldtetők, és azokon alkalmazott egyes *Sedum* fajok komplex értékelése. PhD dissertation. SZIE, Budapest

Szőke, A., Mátyás, T., Szabó, D., Gerzson, L., Forró, E. (2013). Method for the rapid determination of soil physics parameters of extensive green roofs. 12th Wellmann International Scientific Conference. 25th April, 2013, Hódmezővásárhely

Wong, N.H., Chen, Y., Ong, C.L., Sia, A. (2003). Investigation of thermal benefits of rooftop garden in the tropical environment. *Building and Environment,* 38, 261-270.

253/1997. (XII. 20.) korm. rendelet az Országos Településrendezési és Építési követelményekről (OTÉK)