[1.]Anja BUBIK, [2.]Lucija KOLAR

GREENING AS A PERSPECTIVE SOLUTION FOR URBAN MICROCLIMATE MITIGATION – A PILOT STUDY

[1.]Environmental Protection College, Velenje, SLOVENIA
[2.]Complementarium, Institute for research of nature and development of environmental technologies, Celje, SLOVENIA

Abstract: For environments which are ecologically burdened due to their rich natural resources (forests, water bodies, coal…) and dense population (e.g. urban environments), the implementation of green areas provide variety of environmental benefits. Moreover, constant socio-economic pressures and the needs make us to plan thoroughly and prudently our future activities and developmental potentials of urban areas. At the Environmental Protection College (EPC), Velenje, Slovenia in cooperation with the Institute Complementarium (CMP), Celje, Slovenia, we designed a flat green roof pilot model with extensive greening. Based on annual monitoring of different physical and chemical parameters and by observing the growth of selected plants, we evaluated the effectiveness of two different substrates and assessed the relevance and application of extensive greening principle in the urban environment – in the city of Velenje, Slovenia. Our pilot study demonstrated a concrete and successful solution for urban greening in the city of Velenje, which we also plan to implement in the future.
Keywords: greening, pilot models, urban microclimate

1. INTRODUCTION

Green roofs originate from the earliest times of human history, mostly as natural human shelters. They were known by the ancient Greeks and Romans and were the most widespread in Scandinavia and Iceland at the time of the Vikings [1]. In the cities green roofs are becoming very popular again, since the ecological and environmental benefits of their technologies can improve the urban microclimate and thereby return the possibility of sustainable life to the citizens. Beside roofs we can build green walls, facades or even whole infrastructures.

Buildings are important part of our natural environment. Therefore, it is crucial to combine architecture with nature to achieve sustainable urban development [2]. Any construction activity in the environment leads to the reduction of vegetation and humidity, ventilation changes, lack of oxygen and large temperature fluctuations. Based on their characteristics, cities are the most vulnerable areas and at the same time the most important greening environment.

Urban green spaces fulfil a range of different roles, such as aesthetic, sociological and psychological and have economic and environmental purposes. They counteract the urban heat island effect, thereby reducing the energy costs of buildings cooling. Urban greenery minimizes air, water, and noise pollution, and may offset greenhouse gas emissions through CO_2 absorption. They help to distribute rainwater - attenuate a storm water runoff and therefore act as a measure for flood mitigation. Other ecological benefits include raising and preservation of biodiversity, a new habitat creation for certain animal species and the ability to conserve nature [2, 3, 4, 5].

Green areas are also social spaces and areas for recreation and cultural purposes. Health benefits are associated with access to public open space in urban environments that offer an opportunity for health-promoting activities, such as physical activity or rest and relaxation. In this way, they have a direct relationship with the quality of urban citizens' life [5]. For example, parks, playgrounds and other vegetated areas have been associated with better perceived general health, reduced stress levels, reduced depression and provide many advantages, related to human health, like sport and recreation [6].

Due to the fact that over half of the world's population now lives in urban areas, and this proportion is expected to increase to two-thirds by 2050 [6], it is important to evaluate every possibility to increase the quality of life. Therefore, we decided to implement a pilot project, which emphasizes all benefits of greening principles and increases the level of awareness and social responsibility of the citizens.

2. MATERIAL AND METHODS

With the long-term experiment we evaluated the greening potential in the city of Velenje, Slovenia, maybe also as a demonstration project on the flat roof of EPC in the future.

Two flat bottom models were constructed on EPC by undergraduate student. Three different low and slowly growing adaptable plants (Murale white stonecrop (*Sedum album "Murale"*), houseleek (*Sempurirum tectorum*) and blue-green sedge (*Carex flacca*)) were seeded into each model using two different commercial substrates (named A and B), separately (Figure 1). Models were placed outside, on the open balcony of the EPC. Greening process was monitored and evaluated during all four seasons using different physical and chemical parameters (air in substrate pH, air in substrate humidity, total organic matter of substrates). Photo documentation and picture analysis using Image software were used for more representative assessment of the greening effectiveness. Additionally, some awareness campaigns about benefits of greening were organized during the pilot experiments for students and general public.

3. RESULTS AND DISCUSSION

All plants were successfully adapted to selected urban microclimate during first months of extensive green roof simulation experiment. Their growth was equal in both models using different substrates (Figure 2A, 2B). After 6 months, adaptation and growth of individual plants were changed; the blue blue-green sedge was completely dried, the houseleek grew successfully, while the Murale white stonecrop adapted to the urban microclimate even more, as it has grown along the entire area of both models. Based on the results, we can confirm that the sedums are more suitable plants for extensive green roofs in the local microclimate.

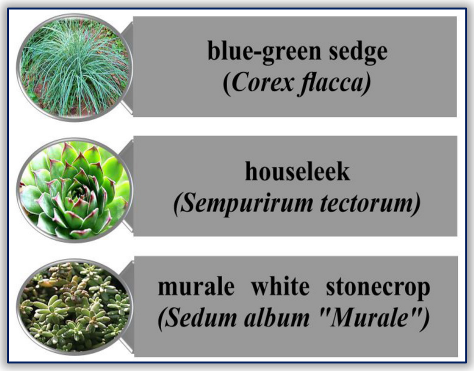

Figure 1. Three different plants (Murale white stonecrop (*Sedum album "Murale"*), houseleek (*Sempurirum tectorum*) and blue-green sedge (*Carex flacca*)) were selected for our pilot study

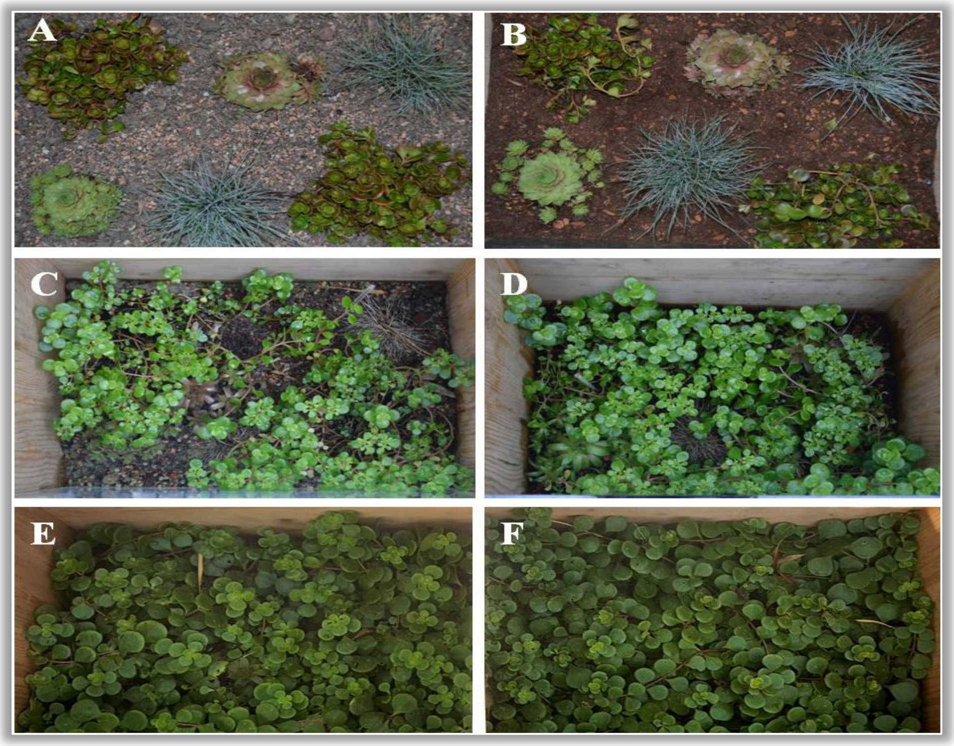

Figure 2. Adaptation of seeded plants to urban microclimate at the beginning (A, B), after 8 months (C, D) and 12 months (E, F) of the pilot experiment

The results of annual measurements of physical and chemical parameters and photo documentation of adaptation process of pilots showed that the selected environment is suitable for the installation of extensive flat roofs. The microclimate is favourable with an average annual temperature of 18.6 ºC and an average relative air humidity of 26.2 %. Temperature varied between T_{min} -0.5 ºC and T_{max} 31 ºC, and no extreme weather event that would jeopardize the existence of pilot models was observed. The substrate temperatures were stable and varied proportionally to the air temperature and were on average 4.3 °C lower and almost the same in both substrates (Figure 3, dashed line trends).

Organic compounds present a small part of the soil, which are very variable and important for quality of the soil. Since the organic matter can affect the physical and chemical properties of the substrate, the total organic carbon (*TOC*) was monitored throughout the pilot study with the aim to determine the suitability and compatibility of our substrates regarding seeded plants. Measurements showed low levels of organic carbon in both substrates (<0.5%), which ranks the substrate into a very low-level grade, in which Slovenia has 9.4% of their surface (summarized by Slovenian Environment Agency). *TOC* values in the substrate B are in average higher for 16 % than the *TOC* of substrate A trough the entire experiment, indicating better growing conditions in consequently greening potential in the substrate B (Tables 2 and 3). With the line to *TOC* measurements, the substrate areas of the pilot model B were also more filled with plants compared to the pilot model A over the entire observation period, indicating that the substrate B in is more successful the selected environment.

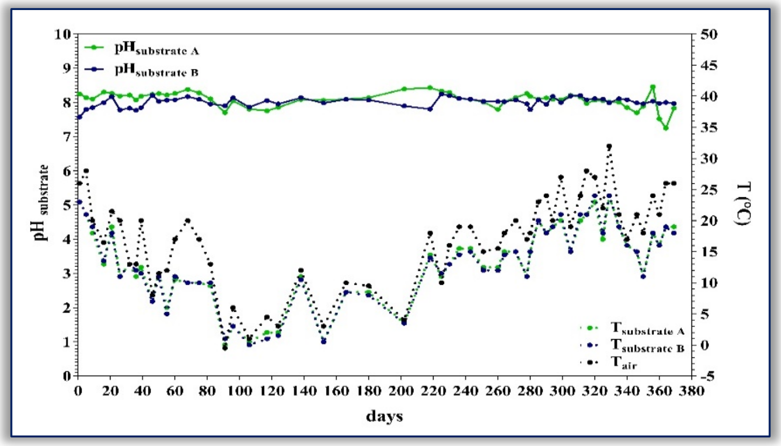

Figure 3. Adaptation of substrate to urban microclimate - annual measurements of air and substrate temperature (dashed line trends) and substrate pH (full line trends)

Table 1. Average season values of parameters for the substrate A

Season	Air temperature (°C)	Substrate temperature (°C)	pH	Relative humidity (%)	TOC (%)
autumn	16.7 ± 6.5	12.2 ± 5.1	8.20 ± 0.13	32.8 ± 14	0.29 ± 0.17
winter	6.1 ± 4.0	4.5 ± 4.2	7.98 ± 0.15	33.3 ± 1.4	0.35 ± 0.02
spring	15.5 ± 4.9	12.8 ± 3.6	8.16 ± 0.20	34.8 ± 6.5	0.30 ± 0.03
summer	23.9 ± 4.9	18.2 ± 4.0	7.98 ± 0.29	31.4 ± 5.5	0.41 ± 0.08
AVERAGE	18.6 ± 7.7	14.1 ± 6.1	8.08 ± 0.24	32.2 ± 9.5	0.35 ± 0.09

Table 2. Average season values of parameters for the substrate B

Season	Air temperature (°C)	Substrate temperature (°C)	pH	Relative humidity (%)	TOC (%)
autumn	16.7 ± 6.5	12.5 ± 5.0	7.94 ± 0.20	31.3 ± 15.1	0.43 ± 0.18
winter	6.1 ± 4.0	4.1 ± 4.2	8.04 ± 0.10	36.8 ± 3.7	0.48 ± 0.02
spring	15.5 ± 4.9	12.5 ± 3.4	8.05 ± 0.13	37.1 ± 9.9	0.33 ± 0.05
summer	23.9 ± 4.9	18.3 ± 4.1	8.04 ± 0.09	34.1 ± 6.1	0.46 ± 0.11
AVERAGE	18.6 ± 7.7	14.2 ± 6.1	8.01 ± 0.15	33.4 ± 10.6	0.42 ± 0.13

Both substrates were slightly basic before planting, i.e. 8.21 for substrate A and 7.86 for substrate B. Average pH value of substrate A during the experiment was 8.08 and of B 8.01, what is 1.6 % lower and 1.8 % higher than the initial value, respectively (Tables 2 and 3). Additionally, during the experiment pH value varied for 24.0 % and 14.9 %, respectively (Figure 2, full line trends; Tables 2 and 3). Interesting trend was observed after analysing and comparing different seasons. In the pilot model with the substrate A, pH value changed up and down throughout 4 seasons; whereas in the model with the substrate B, pH increased during the autumn and then stayed almost constant through the rest of the experiment. Based on pH measurements, substrate A is more sensitive to temperature changes and weather conditions (Figure 4).

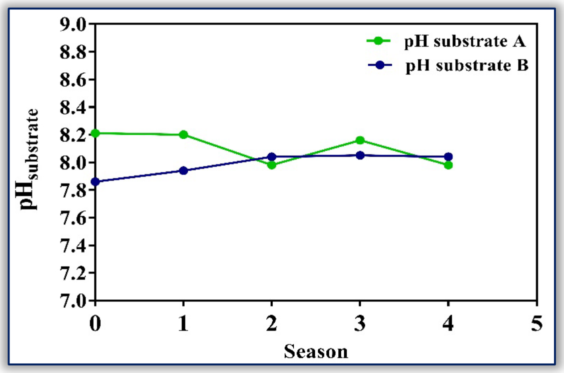

Figure 4. Average pH values of two substrates through 4 seasons

4. CONCLUSIONS

The implementation of our pilot model in selected urban environment was successful. Especially substrate B, which was purchased from the well-known Slovenian supplier of gardening materials, proved to be very promising. Through the study we also gained experience on seeded plants suitability and they adaptation in certain environment. Sedums can adapt to environmental stress (e.g. heat, drought, cold, sunlight) easily, they are limited in height and have a natural appearance; thus they should be and were also experimentally confirmed as the most appropriate. In addition, when the plants are grown in Slovenia, they are perfectly adapted to the weather conditions in which they will grow.

Green roofs should be considered as an important part of urban and local planning. Therefore, it is necessary to develop and establish guidelines to ensure its optimal ecological role in the local natural and social environment. With awareness campaigns we emphasized the importance of the extensive greening principle in the urban environment, also from the perspective of finding a sustainable environmental solution, which ultimately mitigates the urban heat island effects and contributes to reduction of global warming effects. Since, the advantages of green roofs would certainly obtain a higher quality of living space and present one of the important steps regarding better environment in highly industrial city of

Velenje. Our green solutions will be presented also to the wider public in the future through various environmental campaigns and applied research projects.

Note:
This paper is based on the paper presented at IIZS 2018 – The 8th International Conference on Industrial Engineering and Environmental Protection, organized by Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, in Zrenjanin, SERBIA, 11–12 October, 2018.

Acknowledgements
The pilot study arises in the context of the European project Climate KIC, programme Pioneers into Practice, within the group assignment entitled "Greening of buildings" and within the GRACiLIS – Green AnswerS project CLImate Change - Greening in response to climate change (co-financed by the Ministry of Education, science and sport of Republic of Slovenia and the European Union through the European Social Fund from the project calls named "After Creative Paths to Knowledge").

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ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665