World Academy of Science, Engineering and Technology
International Journal of Architectural and Environmental Engineering
Vol:13, No:3, 2019

Effects of Increased Green Surface on a Densely Built Urban Fabric: The Case of Budapest

Viktória Sugár, Orsolya Frick, Gabriella Horváth, A. Bendegúz Vöröss, Péter Leczovics, Géza Baráth

Open Science Index, Architectural and Environmental Engineering Vol:13, No:3, 2019 publications.waset.org/10010157.pdf

Abstract**—**Urban greenery has multiple positive effects both on the city and its residents. Apart from the visual advantages, it changes the micro-climate by cooling and shading, also increasing vapor and oxygen, reducing dust and carbon-dioxide content at the same time. The above are all critical factors of livability of an urban fabric. Unfortunately, in a dense, historical district there are restricted possibilities to build green surfaces. The present study collects and systemizes the applicable green solutions in the case of a historical downtown district of Budapest. The study contains a GIS-based measurement of the eligible surfaces for greenery, and also calculates the potential of oxygen production, carbon-dioxide reduction and cooling effect of an increased green surface. It can be concluded that increasing the green surface has measurable effects on a densely built urban fabric, including air quality, micro-climate and other environmental factors.

Keywords**—**Urban greenery, green roof, green wall, green surface potential, sustainable city, oxygen production, carbon-dioxide reduction, geographical information system, GIS.

I. INTRODUCTION

URBAN green surfaces has a number of positive effects on the environment. These green areas, however, are significantly reduced in the downtowns of cities, bringing a number of negative consequences. As an example, parts of the inner districts of Budapest, capital of Hungary, are such a densely built urban fabric, with minimal green surfaces. The urban fabric here is originated from the 17-18th century, with narrow streets and multi-story apartment houses taking up the space. In the past few years, there have been an increasing number of successful attempts to develop public green areas, contributing greatly to the value of their environment. Apart from government-led actions, the residential demand is also increasing: the gateways, hanging corridors, firewalls and courtyards of the houses are more consistently utilized with planter or potted flowers and plants. These surfaces are commonly joint property of the multi-story apartment houses, but they could serve as usable areas apart from the narrow streets, which are mostly not suitable for larger greenery.

The aim of the study is to survey the possibilities of green surfaces in these semi-private areas of one of the densest urban fabric in Budapest.

II. METHODOLOGY

The first step of the study was to collect the main effects of urban greenery on the dense fabric. Previous studies dealt with the estimations of these effects (see Section VI).

The case study area was chosen as it has one of the lowest green areas per resident value (0.6 m^2/person) [1]. The area was investigated using both GIS methods and field study.

GIS was used to determine the utilizable surfaces of the area. Quantum GIS software [2] was used to measure surfaces, while open source satellite image applications (Google Earth Pro [3] and Apple Maps [4]) were used to verify the function of these areas and its current ratio of built-in surfaces. This was necessary, because the Quantum GIS is only showing the geometry of the main building but does not give information about the ratio of possible green and covered surfaces. An extensive database was built using the above data. The administrative data (house, block number, ownership) of each building were collected using existing repositories [5], [6].

After surveying the satellite images, the green roofs and example solutions for courtyards were examined during a field survey in detail to determine the used technical solutions.

By investigating the building stock of the area, the easily utilizable surfaces were defined: firewalls, courtyards, flat roofs and empty plots. The database above was extended with GIS data about the area of these surfaces.

This was followed by the listing of technical solutions, which can be utilized in such an environment to increase the area of green surfaces.

By using the above-mentioned estimative literature values and the collected surface data, the green surface potential and its effect was calculated.

III. EFFECTS OF URBAN GREENERY

A. Urban Ecology

The green area is a biologically active surface, a living space that modifies its environment through the conditioning effects of vegetation. In order to survive, humanity developed its specific ecosystem, which we call settlements. It is a unique, artificial environment, in which the biosphere, the organic life is present next to the abiotic elements built by humanity. This complex system is called urban ecology [7].

The anthroposphere, or human built environment, contains

Viktória Sugár is lecturer in Szent István University, Ybl Miklós Faculty of Architecture and Civil Engineering, and with the Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary (e-mail: sugar.viktoria@ ybl.szie.hu).

Orsolya Frick, Gabriella Horváth, and András Bendegúz Vöröss are BSc students in Architecture at the in Szent István University, Ybl Miklós Faculty of Architecture and Civil Engineering Budapest, Hungary (e-mail: Frick. Orsolya@hallgato.szie.hu, Horvath.Gabriella.6@hallgato.szie.hu, Voross.Andras.Bendeguz@hallgato.szie.hu).

Péter Leczovics is lecturer in Szent István University, Ybl Miklós Faculty of Architecture and Civil Engineering Budapest, Hungary (e-mail: Leczovics.Peter@ ybl.szie.hu).

Géza Baráth is a Ph.D. student at Szent István University, Gödöllő, Hungary (e-mail: geza.barath@gmail.com).

Open Science Index, Architectural and Environmental Engineering Vol:13, No:3, 2019 publications.waset.org/10010157.pdf

many substances that are not found in nature, affecting mostly negatively the general biology cycle and modifying climatic factors. Due to these interventions, the urban ecosystem is incapable of self-regulation, which projects the need of oversight to solve the problems. Green surfaces are essential to make our cities healthier, through their effect on dust, humidity, temperature, air quality, noise, vibrations and so on [7].

With the vast urbanization, we are gradually overloading the conditions and capacities of our cities. At the same time, increasing the green surfaces could provide a solution to the consequences of this rapid growth, and to damper the more and more extreme effects of climate change [8].

B. Urban Heat Island Effect

The cumulative effect of the urbanization impacts is the Urban Heat Island Effect (UHI), defined as the rise in temperature of any manmade area resulting in a well-defined, distinct ‘warm island’ among the cooler environment. The increased heat store capacity of the urban fabric, supported by the decreased evaporation of plants and growing medium are partially responsible for the effect [9]. The maximum summer UHI intensity of Budapest is 8.5°C; however, experience has shown that higher values may also occur. Added to the already high summer temperatures and increasing number of heat waves, UHI stands as a health risk to the residents, especially the older inhabitants. Previous measurement data also concludes that the increase in temperature in the inner districts of Budapest compared to the outskirts in anticyclonic condition during winter is 2°C [10]. This effect of UHI can be reduced by increasing the green surfaces in our cities.

C. Drainage of Rainfall

The solid finishes of pavements and standard roofs are not holding, rather quickening the runoff of rainwater, which increases the dry, dusty quality of the microenvironment. Experiments verified that already, a 15 cm thick extensive ecological layer is capable to withhold half of the fallen rainwater, thus averagely 8-10 mm of rain remains for example on a green roof. Given a 30 cm growing medium layer on a green roof, an average 75% of the 12-15 mm summer shower can be withheld. This amount of water is utilized by the plants in the green roof, the dust-binding and evaporation is increased, thus improving the microclimate. Furthermore, the water is filtered by the medium, which removes harmful materials like heavy metals, thus less accessing the sewage system and living waters [7].

D. Air Cleaning and Dust-Binding

During photosynthesis, plant cells produce carbohydrates using carbon dioxide, water and solar energy. When conditions are met, oxygen is produced together with water evaporation [11]. Results of the Dresden Technical and Economic University show that 1 m^2 of green wall can bind 2.3 kg carbon dioxide, which produces 1.7 kg oxygen annually [12], [13].

The solid pavements, apart from their disadvantages in the runoff of the water, do not bind the small particles of solid waste. The heat radiating from the surface of the pavements stirs these particles, which present a risk to health. In Budapest, dust produced in such a way can exceed the 2,500 t/year, of which about 380 t/year is originated from residential heating and nearly 1,900 t/year is coming from road transport. The high concentration of these particulates causes cardiac and respiratory diseases. In the case of green surfaces, the dust is filtered and bonded to the leaves [14]. The leaf surfaces also bind other gaseous pollutants, in particular sulfur dioxide, storing it and later taking it to the soil in the autumn [15].

In their study, Pettit et al. [16] built a special measuring device, to define the dust-binding capacity of the green walls. They published results for different species and dust grain sizes. In PM 0.3-0.5 range, the powder has been bonded between 15-30% ratio, and in PM 5-10 range, their results showed 60-90% of bonded ratio (PM, Particulate matter = size of the dust grain in micrometer).

E. Biodiversity, Effect on Humans

The fast population growth and urban development show that in the near future, 80% of the population will live in cities [17]. The sight of greenery is refreshing, and reduces the stresses caused by overcrowding and the dense urban environment. Studies have shown that the proximity of nature improves the quality of life, and there is a close correlation between nature and human mood and health [13].

Biodiversity is essential to the survival of mankind. Due to the high level of urbanization, many species are ousted from their natural environment. Increasing the green surfaces (with emphasis on the indigenous species) can support the maintenance of the diversity.

F. Thermal Shielding and Insulation

Green surfaces dampen and the thermal equalize effect on the building. During winter, they help maintaining the indoor heat, and during summer, they reduce the intensity of warming up. This is especially advantageous in cities, where the above-mentioned Urban Heat Island effect increases the heat even more.

Multiple studies underline the favorable thermal effect of green roofs. As an example, a standard and a green roof were compared via multi-point temperature measurement, and the daily temperature fluctuations were measured during both winter and summer [7]. Overall, it was concluded that the total annual heat fluctuation of the traditional roof was 100°C, while the green roof was only 35°C. It should be mentioned here that the mathematical and physical modelling of a green surface is a complex question, because the most important factor, the thermal conductivity (U, W/m^2K), is dependent on the water content of the growing medium. This amount is not constant in time, and therefore the U is also a dynamic value [7].

Concerning green walls, dynamic temperature simulations were conducted in two different climatic areas for comparison (Greece and France) [18]. The aim was to determine the extent to which the climate affects the green facades. In both cases, the same façade structure was examined. An air conditioner

Open Science Index, Architectural and Environmental Engineering Vol:13, No:3, 2019 publications.waset.org/10010157.pdf

operated from May to September and heating was used from October to April. The temperature was set to 26°C during summer, the heating temperature was 19°C at night, and 15°C in winter. The heating and cooling energy demand of the reference building and its pair with a green wall were compared on both sites. Results show that the heating and cooling energy demand was reduced to half in both countries buildings. Although the cooling demand in the warmer Athenian climate is larger, the green surfaces also halved the demand value. Thus, the relative energy savings in Athens are lower, and the absolute values are the same as the French example [18].

G.Noise Cancellation

A number of research teams are working on establishing the noise attenuation of green surfaces by setting up a mathematical model. It can be concluded that the given the disordered surface of the leaves, the sound absorbing ability is increased. Also, the structural noise cancelling is higher in case of a larger medium layer [15].

H.Vaporization

The green surfaces obtain most of the energy from sunlight. The plants, however, use only part of the radiation that reaches the surface, and the other part is reflected. The vegetation transmits part of the received heat into the medium or soil. The energy that has not been led by the plant's sprout is utilized in the life processes. A small part of the energy is used in the constructing of tissue, but most of it is utilized for water evaporation. This is called latent heat, which does not heat up the environment. The vegetation thus has a cooling effect, which can be examined through the amount of evaporated water.

Evaporation also happens in and on the surface on the soil by heat dissipation. The evaporation of the vegetation and soil together are called evapotranspiration.

Evapotranspiration depends on a number of parameters such as the plant species, its health, age, the amount of available water in the soil, the weather, etc. Therefore, in our calculations detailed below, each case considered a minimum and maximum evaporated water value of summer [19].

I. Disadvantages

With the appearance of the green surfaces, the development of microecology begins first with arthropods and rodents, as the vegetation offers a safe habitat for them.

As with any façade cladding and gravel load on the flat roofs, the green surfaces result in increased load on the building structures. Here, especially the vegetation and its holding structure and growing medium should be calculated as excess load, thus the appropriate strength of the structures below is important.

The same as the gardens are cared for and nursed, the green roofs and façades also require maintenance; otherwise, they will dry out. The destroyed vegetation thus achieves the opposite of the desired aesthetic effect. Regular water supply and maintenance should be ensured.

IV. TECHNICAL SOLUTIONS

A. Vertical Surfaces, Green Façades

Green façade is a space delimiter structure, with greenery connected [7]. There are multiple forms of solution; the most commonly used are detailed below (see Fig. 2):

Vegetation (climbed) on auxiliary structure or wall: In this case, only runner plants can be used, considering whether the branch system requires support. The plants may grow directly from the soil, run down from a green roof, or intermediate ceiling. The advantages of the solution are that it is inexpensive, does not require much maintenance and adds only little extra weight to the building structure. The disadvantages are the slow growth and the limited number of usable plants [7].

There are solutions *without soil connection*, for example *hydroponic green walls and walls with growing medium.*

The hydroponic wall was patented by a French botanist, Patrick Blanc. It is a technology, where a growing medium is not used. The plants are placed in small pockets or niches, so their roots are directly in contact with water/liquid containing nutrients. The biggest advantage of the design is the lower weight resulted by the missing growing medium. At the same time, this solution is the biggest disadvantage, as the water must be constantly circulated, making the technology expensive, not to mention that a loss of electricity can destroy the plants [20].

In the case of green walls with growing medium, the advantage of the solution is that the medium retains the microorganisms necessary for the plants, and also there is no need for artificial water circulation. The medium is, however, a heavy structure which requires well established support.

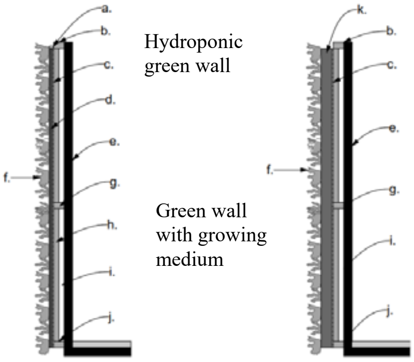

Fig. 1 The differences and similarities between hydroponic and growing medium based green wall. a. water sprinkler; b. upper structural console; c. PVC water insulation layer; d. root bearer layer; e. building wall; f. plants; g. middle structural console; h. auxiliary load bearing structure; i. air gap; j. bottom structural console; k. growing medium in panels

B. Horizontal Surfaces, Green Roofs

Green roofs are most commonly grouped into *extensive* and *intensive* subgroups. Fig. 2 illustrates the differences of the structure.

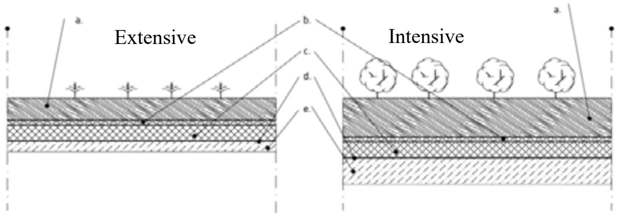

Fig. 2 The differences and similarities between an extensive and intensive green roof. a. growing medium; b. drain system with water table; c. heat insulation; d. separating layer and water insulation; e. flat roof slab

The *extensive green roofs* are characterized as low-maintenance, self-sustaining green surfaces. Built with an average 8-20 cm growing medium and planted with wide-tolerance species or pre-manufactured vegetation duvet, the multi-layered structure should have a sufficient drainage system. These roofs are generally not utilized as living spaces, and only approached when some maintenance is needed. Therefore, the construction of extensive roofs is mainly to achieve ecological goals, not to create usable gardens. This is, however the most commonly used type, mainly because its ecological impact is outstanding, but at the same time economically feasible. Its other advantage is the relative low weight, enabling the system to be used on almost every flat roof (1.6-2.4 kN/m^2) [21].

Contrary to the above, *intensive green roofs* are commonly built to be used as gardens. The type is constructed with at least 40 cm growing medium and adequate drainage. Not only grassland, but shrub and canopy can be planted here. Most often, perennial ornamental plants and wood-stalks are used, taking into account that there are more extreme factors affecting the plants on the roof: the annual and daily temperature fluctuation, the UV radiation, the wind load, the dust and air pollution are all increased here. The intensive roof requires regular and careful maintenance, and long-term nutrient supply of the root system. This kind of green surface can only been built on a flat roof with higher load bearing capacity (2-15 kN/m^2 added load), sufficient water insulation, and under a 10° slope to prevent erosion [7].

C. Inclined Surfaces

Slanted green roofs are not so different from the horizontal examples. The supporting structure is slightly different, extended by anti-slip devices (plaits, anti-slip fabric, etc.) but the layers of the green roof are generally the same.

V. CASE STUDY AREA

A. Introduction of the Area

The historical downtown of Budapest is one of the most densely populated areas in the county. The building stock is characterized by the traditional, multi-story apartment houses with courtyard built during the turn of the 19-20th century [22].

Fig. 3 shows an example of the aforementioned type. Usually, this type has been functioning as condominium with different size and variously equipped flats. The building is constructed around a courtyard, which can be accessed through a gate on the street front. Near the gate is the main staircase. The flats on the upper stories can be entered from the hanging corridors running parallel along the walls. This type is mostly built in an unbroken row along the narrow streets, connecting to each other with firewalls on three sides. The roof is nearly in all cases a pitched structure.

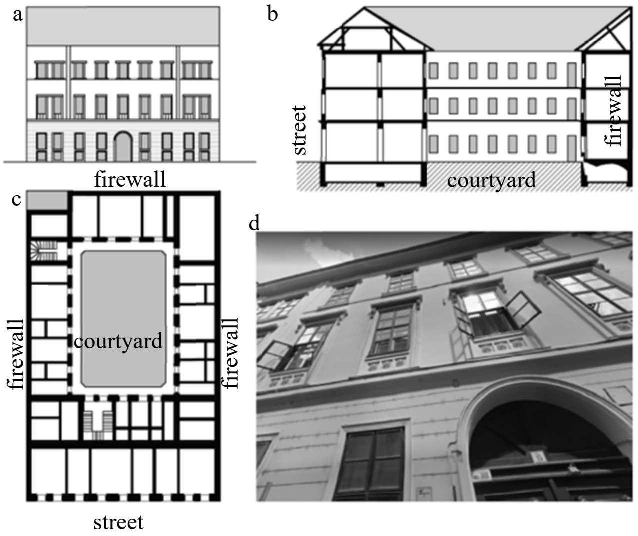

Fig. 3 Characteristic multi-apartment residential building in Budapest. (a) Street front façade. (b) Cross section, (c) First floor plan, (d) Façade detail with historical style elements

The surveyed area is situated in the statistical boundaries of the 7th district. This part is called Belső-Erzsébetváros (Inner-Elizabethtown), containing 475 buildings on 0.6 km^2 (Fig. 4). Compared to its size, the population is high at 26,000 persons/km^2, forming the most densely populated district of Budapest [23].

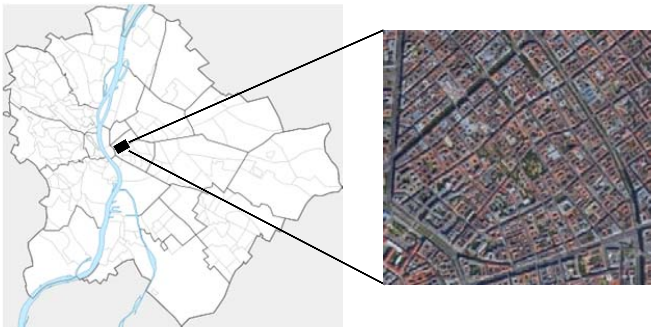

Fig. 4 The Case study area in today's District 7 of Budapest [3]

B. Analysis of Greenery in the Area

The arrangement of the present green surface system is not continuous, rather island-like. A few public parks and green surfaces can be found, with an isolated line of trees.

The density of the area (both built and population) is prominent, even compared to the average Budapest values. The construction regulation at the turn of the 19-20th century - which was the main construction activity time, and most of the buildings were built in this period- supported the evolution of

Open Science Index, Architectural and Environmental Engineering Vol:13, No:3, 2019 publications.waset.org/10010157.pdf

such a dense fabric. The policy of the time enabled a very low ratio of courtyard compared to the full area of the plot, only 15-25% was to be left empty [24].

In the case of these traditional multi-story apartment houses, the firewalls and courtyards can be utilized as green surfaces.

Originally, all firewalls marked on the example buildings in Fig. 3 should have been connected to a neighbor, but due to the constantly changing building regulations and demolitions after the World War 2 bombings, there are considerable areas of empty, unaesthetic firewalls (Fig. 5).

Fig. 5 Two of the many empty firewalls in the case study that could be used as green walls

The empty plots are partly resulted by the above historical events [24]. Many of these plots are today used for car parking (Fig. 6); however, these sites could be the optimal location for public parks, while vehicle storage could be solved by building multi-story garages, which are more efficient than the present solution.

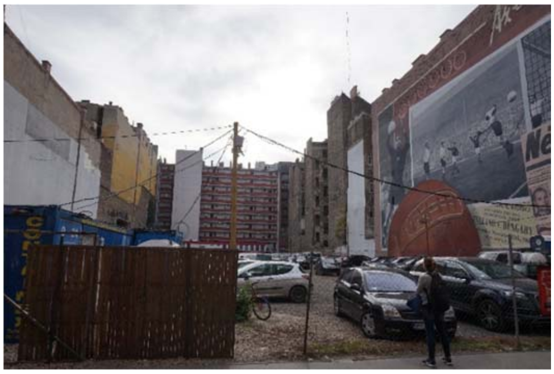

Fig. 6 Empty plot used for parking in the case study area

Apart from the above, historical buildings, the newer ones built during the 20th century have flat roofs and backyards, which also can be considered for greenery. These modernist and contemporary buildings are less in number, only 15% of the full stock. A previous study shows that in Budapest, approximately 6.5 km^2 flat roof can be found (only 3-5% of the built-in area), of which, 3 km^2 could be utilized as green roof. The remaining area would not be suitable based on structural, economical or other reasons [25].

In our case study area, the ratio of utilizable flat roofs are similarly low, but there are existing examples here also (Fig. 7).

The residents' demand for greenery is evident, if we take a look at the inner courtyards. Mostly trees and other running plants can be observed, in some cases, full self-made parks are created (Fig. 8). Even where the courtyard is fully paved (because of a cellar underneath or other reasons), flower pots are often placed for decoration (Fig. 9).

Fig. 7 Flat roof utilized as green roof in the case study area

Fig. 8 A self-made garden in a courtyard

Fig. 9 Flower pots are placed where greenery otherwise cannot been planted

VI. EFFECTS OF URBAN GREENERY, ESTIMATIVE CALCULATIONS

A. Green Area Potential

As detailed in Section II, by combining GIS and field survey, an extensive database was created to be able to calculate the existing, and the potentially utilizable green surface areas. Table I shows the results of the above examination. It can be concluded, that more than tenfold of the presently used green surfaces could be utilized in the area. By only utilizing the courtyard, as the simplest technical and economical solution, the green surfaces could be increased by more than 54,000 m^2.

In the below detailed calculations, the green surface areas from Table I were used to determine the effect of greenery. The effects were calculated both for existing and potential green surface areas. Table II summarizes the calculation results.

TABLE I
EXISTING AND POSSIBLE GREEN SURFACES IN THE CASE STUDY AREA

Utilizable surfaces	Quantity (m^2)	Out of utilizable surfaces, green area	Existing green surface (m^2)	Potential green surface (m^2)
Total flat roof area	58,329	Green roofs	3,390	54,939
Total inner courtyard area	85,290	Green courtyards	15,497	69,793
Total empty firewall area	125,378	Green walls	1,848	123,530
Total empty plots	8,998	Empty plots used as parks	0	8,998
Total utilizable area	277,995	-	20,735	248,262

TABLE II
EXISTING AND POSSIBLE GREEN SURFACES IN THE CASE STUDY AREA

Effect of greenery	Effect amount and value	Existing green surface	Potential green surface	Effect of existing green surface	Effect of potential green surface
CO_2 binding	2,3 kg/m^2/year [12]	46,828 m^2	257,260 m^2	107,704 kg/year	591,698 kg/year
O_2 production	1,7 kg/m^2/year [13]	46,828 m^2	257,260 m^2	79,608 kg/year	437,342 kg/year
Evaporation of trees	(average) 2.5 l/day/tree [26]	470 pc	Approx. 1,500 pc	1,175 l/ day	3,750 l/ day
Heat withdrawal by the evaporation of trees	2,256 J/kg water evaporation heat [27]	1,175 l/ day evaporated water	3,750 l/ evaporated water	2,650 kJ/day	8,460 kJ/day
Evaporation of green wall units	0,68 l/day/m^2 [28]	1,848 m^2	123,530 m^2	1,257 l/day	84,000 l/day
Heat withdrawal by green wall units	2,256 J/kg water evaporation heat [27]	1,257 l/day evaporated water	84,000 l/day evaporated water	2,835 kJ/day	189,504 kJ/day
Evaporation of green roofs and courtyards	4 l/day/m^2 [29]	18,887 m^2	124,732 m^2	75,548 l/day	498,928 l/day
Heat withdrawal by green roofs and courtyards	2,256 J/kg water evaporation heat [27]	75,548 l/day evaporated water	498,928 l/day evaporated water	170,436 288 kJ/day	1,125 582 kJ/day

B. Oxygen Production and Carbon-Dioxide Reducing Potential

As mentioned in Section III, 1 m^2 of green wall can bind 2.3 kg carbon dioxide, and produce 1.7 kg oxygen annually [12], [13]; thus yearly, almost 600 tons of CO_2 and 440 tons of O_2 could be produced.

C. Evaporation and Heat Withdrawal of Trees, Green Walls

According to Wang et al. [26], who examined seven and 17 year old apple trees for several years, the average evaporation rate is 1-4 mm /day/tree. Thus, 3,750 l of water could be evaporated by the possible 1,500 trees, which can improve the dusty, dry microclimate. As the water evaporation heat is 2,256 J/kg [27], with 1,500 trees, daily almost 8,500 kJ heat could be eliminated by the evaporation, helping to reduce the UHI effect.

Koroknai et al. [28] deals with the assessment of a certain green wall module system, called ‘HIB’. The study contains examinations for three combinations of plants in the module, their water supply, evaporation and heat withdrawal. The ‘HIB’ system consists of polypropylene crates with 0.24 m^2 of vegetation per unit. Measurements have been taken to determine the amount of water evaporated from a box per day.

The first plant combination (*Ficus benjamina* ’Variegata’, *Ficus benjamina*, *Tradescantia zebrina*) resulted in 0.96 l/day/m^2, the second in 0.68 l/day/m^2 (*Epipremnum aureum*, *Tradescantia pallida*, *Chlorophytum comosum* 'Variegatum'), and the third in 0.44 l/day/m^2 (*Pseuderanthemum rericulaíum*, *Callisia repens*, *Tradescantia zebrina*) of water evaporation [28]. As a middle ground, in our current calculation, the second plant combination was used.

By utilizing all the empty firewall surfaces for green walls 84,000 l/day water could be evaporated, withdrawing 189,504 kJ heat per day.

Straatmann et al. [29] dealt with measuring short-crop reference evapotranspiration of herbaceous plants, concluding at 2-6 l/m^2/day. These kinds of plants could be used for green roofs and courtyards also. If we calculate with an average 4 l/m^2/day evaporation and considering the existing and potential green roof and courtyard areas, almost 500 thousand liters of water can be evaporated with more than 1 million kJ heat withdrawal.

VII. CONCLUSIONS

Today, green surfaces play increasingly important role in facing the vast urbanization and the effects of climate change and Urban Heat Island. The densely built in settlements require more greenery to improve the microclimate. The advantages of green areas in these districts are: oxygen production, carbon-dioxide reduction, evaporation, heat withdrawal, dust-binding etc.

In Hungary, the downtown of Budapest is the most densely built and populated area. The building stock consists of mainly multi-story apartment houses with courtyards, built in an unbroken row along the narrow streets. In this urban fabric, very low amount of green area can be found.

In the current paper, the authors used GIS and field survey methods to calculate the existing and potentially utilized green surfaces (excluding public parks, which are out of the scope of the current study, only considering the semi-private zones of the buildings). Given the restrictions of the urban fabric, the potential green surfaces are: courtyards as gardens, flat roofs as green roofs, and empty firewalls as green walls.

It can be concluded that a significant amount of potential green area is found in the case study area. In using these surfaces, a large amount of oxygen (437,342 kg/year) can be produced, as well as carbon dioxide (591,698 kg/year) reduced. The evaporation and heat withdrawal potential are also high: trees (3,750 l/ day; 8,460 kJ/day), green wall units (84,000 l/day; 189,504 kJ/day) and horizontal surfaces (498,928 l/day, 1,125 582 kJ/day).

The above amounts could considerably improve the micro-climate of the case study area, also increasing the life quality of residents and reducing the health risks associated with the dust and excess heat typical of the urban heat island.

REFERENCES

[1] Renewal of historical urban fabric (Hun: Historikus városi szövet megújítása), 2016. Budapest University of Technology and Economics, Faculty of Architecture. https://issuu.com/lakotanszek/docs/1_1_mell__klet_kezel__si_k__zik__ny (2019.03.01).

[2] Quality GIS software: https://www.qgis.org/hu/site/ (2019.02.02).

[3] Google Earth Pro https://www.google.com/earth/versions/ (2019.01.22).

[4] Apple maps https://mapsconnect.apple.com/ (2019.02.02).

[5] B. Nagy: Budapest VII. kerület Belső Erzsébetváros rehabilitációs szabályozási terve (Budapest District VII Inner-Elizabethtown Regulation Plan). 2008.

[6] A. Déry: Budapest Architectural Topography 3., Theresatown – Elizabethtown, 6th-7th District (Hun: Budapest építészeti topográfia 3. – Terézváros-Erzsébetváros, VI-VII. kerület). Budapest, Terc Kft. 2006. ISBN 978 963 953 537 4.

[7] I. Hidy, L. Gerzson, J. Prekuta: Green roof, the crown of the urban roofscape (Hun: A zöldtető a városi tetőtáj koronája), TERC Kereskedelmi és Szolgáltató Kft. Szakkönyvkiadó Üzletága, Budapest, 2011, p.29.

[8] I. Nagy: Theoretic approach to urban ecology (Hun: Városökológia elméleti megközelítése), p. 542., http://www2.sci.u-szeged.hu/eghajlattan/baba/NagyImre.pdf (2017. 10. 20).

[9] T. R. Oke: The energetic basis of the urban heat island. Q. J. R. Meteorol. Soc. 108, 1982, pp. 1-24.

[10] I. Hadnagy, K. Hubay, I. Kolozsvári, E. László, Sz. Szanyi, Z. Varga: Klímaváltozás a Kárpát-medencében: múlt, jelen, jövő, 2013.

[11] http://tavoktatas.kovet.hu/tartalom_belso-legter_oxigen.htm (2017.11.11).

[12] Hochschule für Technik und Wirtschaft Dresden, 2009: http://hu.helix-pflanzensysteme.de/de/content/articles/hidrokulturas-noevenyrendszer-anyag-esenergiamerlege-68/ (2015.10.09).

[13] B. Vágner: Szendvicspanel elé rögzített zöldhomlokzati rendszerek hőtechnikai hatásainak mérése. Budapesti Műszaki és Gazdaságtudományi Egyetem Építészmérnöki Kar Épületenergetikai és Épületgépészeti Tanszék: Tudományos Diákköri Konferencia 2015. p.5.

[14] http://www.tankonyvtar.hu/hu/tartalom/tamop425/2011_0001_521_Novenyek-a-kertepiteszetben/ch03s15.html (2017.10.17).

[15] K. Csibi, P. Dezsényi, M. G. Fári, J. Koroknai, R. Pataky, F. Szentkirályi-Tóth: Zöldhomlokzatok. Függőleges zöldfelületek tervezésének, kivitelezésének műszaki és kertészeti útmutatója. Budapest Főváros Városépítési Tervező Kft., Budapest, 2016, p. 31.

[16] Pettit, P.J. Irga, P. Abdo, F.R. Torpy: Do the plants in functional green walls contribute to their ability to filter particulate matter? In: Building and Environment, Volume 125, 2017, Pp. 299-307, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2017.09.004.

[17] C. Finke, J. Osterhoff: Zöld homlokzatok. Budapest, CSER kiadó, 2002.

[18] D. Rabah, B. Emmanuek, B. Rafik: Analysis of thermal effects of vegetated envelopes: Integration of a validated model in a building energy simulation program. In: Energy and Buildings, Elsevier, 86 (2015) 93–103.

[19] D. J. Sailor: A green roof model for building energy simulation programs. In: Energy and Buildings, 2008., 40(8), 1466-1478. DOI: 10.1016/j.enbuild.2008.02.001.

[20] G. Vizi: Zöldhomlokzatok vagy élőfalak? Korszerű homlokzatburkolati technikák. SZIE-YMÉK, Épületszerkezettan IV. Előadás.

[21] http://zeosz.hu/extenziv-zoldtetok/ (2017.11.11).

[22] A. Perczel: Védtelen Örökség - Unprotected Heritage, Lakóházak a Zsidó Negyedben- Residential Buildings In The Jewish Quarter. Városháza, 2007, pp. 13-29.

[23] Á. Szabó: A pesti belváros tömbjeinek sűrűsége, in *Budapest 2050, A belvárosi tömbök fennmaradásának esélyei (Budapest 2050, The chances of the subsistence of Budapest Downtown)*, pp 46-57., 2012.

[24] I. A. Edvi: *Budapest műszaki útmutatója* 1896 (Technical Guide of Budapest 1896), Budapest, Terc Kft., pp. 56-67. 2005.

[25] G. Darázs: Zöldtető beépítés ösztönzése. Budapest, 2010.

[26] D. Wang, L. Wang: Dynamics of evapotranspiration partitioning for apple trees of different ages in a semiarid region of northwest China. In: Agricultural Water Management, Volume 191, 2017.

[27] https://www.engineeringtoolbox.com/water-properties-d_1573.html (2019.02.02).

[28] J. Koroknai, R. Pataky, T. Kaprinyák, M. G. Fári: HIB zöldfal-modulok vízháztartásának értékelése. II.Szobanövény-összeállítás vizsgálata árnyékolt kültérben. In: Horticulture 48. évf. 3. sz. / 2016, pp. 76-83.

[29] Z. Straatmann, G. Stevens, E. Vories, P. Guinan, J. Travlos, M. Rhine: Measuring short-crop reference evapotranspiration in a humid region using electronic atmometers. In: Agricultural Water Management, Volume 195, 2017.