FLAT ROOFS POTENTIALS FOR IMPLEMENTATION OF URBAN AGRICULTURE

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Summary: *The paper deals with the potentials of flat roofs for implementation of urban agriculture, since they have proved to be a very suitable form of built environment for application of this increasingly present concept of sustainable urban development. The research focus is on the analysis of the potentials of different types of flat roofs for the implementation of different categories of urban agriculture, as well as on the consideration of the ecological, economic and social benefits of this urban agriculture specific mode.*

Keywords: *Urban agriculture, urban rooftop agriculture, flat roofs, potential, benefits of applications*

1. INTRODUCTION

Guided by various motives from one country to another, urban agriculture has spread over recent decade as a global social movement for the creation of sustainable communities, i.e. social networks that are based on a common attitude towards nature, mostly environmentally-friendly food production and the holistic principle of the organization of community. Consequently, sustainable urban production has become a growing field of interest among academics and professionals [1].
If it obtains formal, institutional and organizational support in national and local contexts, urban agriculture is also defined and applied as a concept of sustainable urban development that is in synergy with other current urban concepts and models such us Smart Growth, New Urbanism, Compact City, Ecological Urbanism, WSUD etc. In this case, urban agriculture integrates into urban planning and design, and consequently architectural design, with the most viable results at the local level.

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Although the application of various categories of urban agriculture is possible within many elements and forms of the built environment, it appears that the flat roofs, both on existing and newly planned buildings, have been shown to be an exceptionally suitable form for its application in many urban conditions, with significant benefits in terms of ecological, economic and social developmental aspects. In addition to the consideration of the basic charachteristics of urban agriculture and urban rooftop agriculture as its specific, building-based form, the research focus in this paper is on following:

1) Analysis of the potentials of different types of flat roofs for the application of different categories of urban agriculture, which represent two large typological groups of urban agriculture: a) non-commercial and b) commercial urban agriculture.
2) Understanding the effects and benefits of application, i.e. consideration of the ecological, economic and social benefits of specific mode of urban agriculture which is based on the use of flat roofs - urban rooftop agriculture or urban rooftop farming.

In addition to analyzing conceptual frameworks, the research is based on the analysis of examples of good practice from the countries that recognized the importance of sustainable urban development and incorporated the concept of urban agriculture into the system of urban planning and design, as well as architectural design.

2. METHODOLOGY

In analyzing the connection and relationship between the different categories of urban agriculture and the different types of flat roofs, as well as in exploring the benefits of the implementation of urban rooftop agriculture, the methodological framework is based on an analytical approach which relies on description, analysis and comparative analysis. The best practice examples which represent different categories of urban agriculture and different types of flat roofs are chosen for the research platform.

3. URBAN AGRICULTURE - SETTING THE CONTEXT

Although it has been recognized in various forms almost from the emergence of the first cities, urban agriculture positioned itself as a globally social movement and generally accepted sustainable urban development approach in the last century. In its core is primarily food security, but in the recent decades urban agriculture has evolved and became multifunctional, including following functions: 1) providing environmentally-friendly food, 2) educating and promoting health habits, and 3) building and empowering communities [2][3][4]. Today, urban agriculture is present around the world as a response to the increasing urban population, climate change negative effects, the growing environmental awareness of the industrial food system and the need of addressing social gaps [5][6].

Accordingly, reasons for urban agriculture and its manifestation vary: a) in developing countries the focus is on the growth and strengthening of the local economy (for instance, years ago Cuba partly converted to organic agriculture in or near cities and to establishing local markets); b) in Western countries it is often an expression of a new lifestyle or a necessity to reduce decline and unemployment, with the focus on healthy food production,

return to nature, environmental protection, strengthening of social connection etc. (for instance, community gardens in New York and Paris give poor communities, in particular, more independence, more social cohesion and therefore support the emancipation process); and c) in some countries it is a part of the cultural milieu and tradition (for instance Russia, where 30 % of the total food grown in the country and 80 % of the vegetables are produced on the dachas) [7].

Regardless of the different motives, the United Nations Development Program [8] estimates that 15% of food worldwide is grown in cities and this figure could be significantly expanded in the next 20 years, largely as a result of the increase in urban agriculture in developing countries, but also in Russia and North America. At the same time, more than 800 million people around the world are engaged in urban agriculture. For instance, currently 14% of Londoners already grow some food in their gardens [9], while the number of Moscow families engaged in food production increased from 20% to 65% from 1970 to 1990 [7].

Similarly to the reasons of urban agriculture, its definitions also vary. The main differences between them are determined by spatial, production, functional and market specificities. According to general and broad definition of Food and Agriculture Organization (FAO), urban and peri-urban agriculture can be defined as growing the plants and raising the animals within and around cities [10][11]. A similar definition is given by the Research Center on Urban Agriculture and Food Security (RUAF), but with further elaboration regarding to its main characteristics [12][13] - according to this definition, the most important characteristic of urban agriculture, which differs from rural, is not so much in (urban) location as in its integration into the urban economic and ecological system and interaction with them. Mougeot [14] also concludes the same and considers that urban agriculture, as an integral part of the urban economic, social and ecological system, uses urban resources (land, labour, urban organic wastes, water), produces for urban citizens, is strongly influenced by urban conditions (policies, competition for land, urban markets and prices) and impacts the urban system (effects on urban food security and poverty, ecological and health impacts). Environmental Protection Agency (EPA) definition focuses on spatial and environmental aspect of urban agriculture - city and suburban agriculture takes the form of backyard, roof-top and balcony gardening, community gardening in vacant lots and parks, roadside urban fringe agriculture and livestock grazing in open space [15][16]. Within this definition urban agriculture is seen as an important source of environmental and production efficiency benefits, because the use of best management practices and integrated farming systems can protect soil fertility and stability, prevent excessive runoff, provide habitats for a widened biodiversity, reduce the emissions of CO2, increase carbon sequestration, and reduce the incidence and severity of natural disasters such as floods and landslide.

RUAF describes eight categories of urban agriculture (Fig. 1), divided into two groups: a) non-commercial urban agriculture, and b) commercial, market oriented urban agriculture [17]. Non-commercial group include the following categories: 1) micro-farming on balconies, roof-top terraces, gardens and window sills; the yield is mostly for own consumption or is shared with friends and family (crops include vegetables, fruit, herbs and flowers, sometimes combined with the keeping of chickens and rabbits); 2) garden plots on specially-assigned land; gardening here is also generally to meet own needs and shared with friends and family and there are no commercial objectives; 3) institutional gardens which serve mostly an educational, therapeutic or social purposes within

hospitals, schools, prisons, etc. [17][18]. Market oriented group include the following categories: 1) small-scale commercial or semi-commercial agricultural and horticultural businesses that grow vegetables, fruit, herbs and plants and are usually situated on the edge of the city - these businesses produce for their own use and for the market; 2) small-scale commercial or semi-commercial stock-breading businesses or aqua-culture businesses keep poultry, have a number of cows and pigs or cultivate fish and shellfish. They produce for their own use and for the market; 3) specialized businesses grow products such as mushrooms, potted plants, flowers, etc. They grow primarily for the market and can grow to larger businesses; 4) large-scale agro-businesses that are usually situated on the edge of the city, extremely specialized, equipped with advanced technology, use fertilizer and concentrates. They produce for the market; and 5) multi-functional urban agricultural businesses also provide, in addition to agricultural products, farm tourism, education, recreation, agrarian nature conservation, pick-your-own farms, etc. [17] [18]. In addition to these, there are also other forms of urban agriculture in Western metropolises, such as: 1) guerilla gardening - vacant lots or roofs in the city are transformed into gardens, usually accompanied by fun or playful activities (Fig. 1); and 2) multi-cultural gardens or community vegetable gardens are established to offer gardeners of different nationalities a place to meet [18].

Figure1. Different categories of urban agriculture

a) Non-profit, child-friendly micro-farming (EVA-Lanxmeer, Culemborg);
b) Non-profit community garden in inner courtyard (Wippolder, Delft);
c) Small-scale semi-commercial greenhouses (EVA-Lanxmeer, Culemborg);
d) Commercial urban farm on the edge of the city ('Hoeve Biesland' near Delft)

4. FLAT ROOF IN CONTEXT OF URBAN ROOFTOP AGRICULTURE

Within the city level and local food movement, urban agriculture experiences have spread over cities in the last years with the aim of increasing the urban area devoted to food production thereby contributing to urban food security and resilience. On the other hand, there is pressure on the land for urban agriculture and therefore on urban food production. For instance, although in the 14 largest cities in China more than 85% of the vegetables are produced in the city, at the same time 20% of the best agricultural land in China is being sacrificed to the construction and expansion of new cities [19].
In conditions of densely populated urban areas and spatial limitation within them, as well as in conditions of unreasonable expansion of urban territory when often high quality agricultural land is occupied, practitioners/residents and planners have found on the flat roofs of the existing or newly developed buildings an empty space for setting up food production [20], which led to the development of *urban rooftop agriculture as a type of specific, building-based form of urban agriculture.*
Within the literature, building-based urban agriculture (Fig. 2) has been conceptualized as: 1) vertical farming [21], 2) building-integrated agriculture (BIA) [1], and 3) zero-acreage farming (ZFarming) [22]. The last, recently introduced term Zero-acreage farming included all types of urban agriculture characterized by the non-use of farmland or open space, thereby differentiating building-related forms of urban agriculture from those in parks, gardens, urban wastelands etc. [22]. Therefore, this definition encompassed from vertical greenhouses or indoor farms to rooftop gardens, rooftop greenhouse or edible walls, regardless the type of technology used [4]. Within existing buildings, current practices are edible walls, indoor farming and rooftop farming.

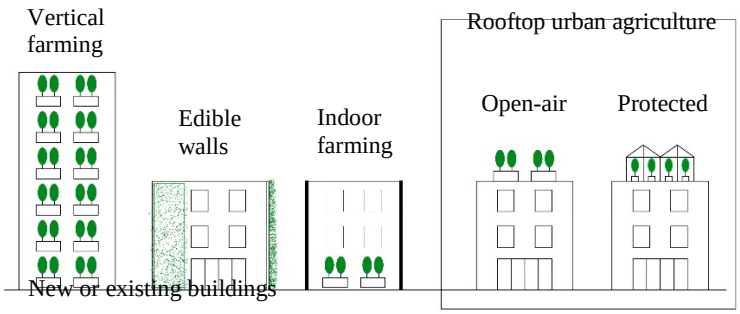

Figure 2. Different concepts and forms of building-based urban agriculture

Urban rooftop agriculture can be defined as development of farming activities on the top of the buildings by taking advantage of the available spaces on roofs or terraces. Based on key criteria such as: groups/categories of urban agriculture (1), type of farming (2), type of ownership (3), and cultivation techniques (4) the following main typologies of urban rooftop agriculture can be defined:

1) Non-commercial and commercial (market oriented).
2) Open-air rooftop agriculture and protected rooftop agriculture (i.e. rooftop greenhouses).
3) Private, semi-private, common and squatted urban rooftop agriculture.

4) Soil production based urban rooftop agriculture (refers to the use of soil as growing media for vegetables production), soil-less production based urban rooftop agriculture (refers to the use of alternative substrates to soil as growing media for vegetables production) and hydroponic production based urban rooftop agriculture (refers to the use of water as the growing media for vegetables production).

The experiences of many countries indicate that the open-air rooftop farms and gardens are the most common type of urban rooftop agriculture [23]. Based on the existing typologies of urban agriculture as well as types of flat roofs, for the purpose of this research a typology of the forms of the organization of rooftop farms and gardens has been formed. The typology is shown in Table 1.

Type of roof	Form of organization of rooftop farms and gardens	Category of urban agriculture	Type of farming	Type of ownership	Example/ Illustration
Green roof	Continuous soil layer over the roof surface	Non-commercial Commercial	Open-air	Private Semi-private Common	
	Raised beds and containers	Non-commercial Commercial	Open-air	Private Semi-private Common	
Flat roof	Separate small elements - pots and gardeners	Non-commercial Commercial	Open-air	Private Semi-private Common	
	Greenhouse	Non-commercial Commercial	Protected	Private Semi-private Common	
	Modular farm units	Non-commercial Commercial	Protected	Private Semi-private Common	
Combined	Combined	Non-commercial Commercial	Open-air Protected	Private Semi-private Common	

Table 1. Forms of organization of rooftop farms and gardens

Following this typology, in practice can be identified different types of urban rooftop agriculture such as commercial rooftop greenhouses, socially-oriented rooftop greenhouses, rooftop farms, socially-oriented rooftop gardens (which encompass from community rooftop gardens in residential buildings to therapeutic rooftop gardens in hospitals, for instance) etc. Non-commercial urban rooftop agriculture can though range from private rooftop farming in terraces to rooftop gardens addressing social inclusion of low-income residents or ethnic groups.

5. URBAN ROOFTOP AGRICULTURE - BEST PRACTICE EXAMPLES

This section gives a brief overview of best practice examples that represent the different, already elaborated, types and forms of urban rooftop agriculture, as well as multiple benefits of its implementation.

A) Brooklin Grange - Commercial, open-air private rooftop farm, organized in form of continuous soil layer over the roof surface

The Brooklyn Grange is one of the most known rooftop farms in New York, USA. Founded in 2010, the company already has two rooftop farms in Long Island (4000m^2) and Brooklyn (6000m^2), on the roof of the existing business building (Flagship) and Navy yard building (Fig. 3a), as well as a bee apiary on multiple rooftops in New York. Beyond food production, Brooklyn Grange participates in youth education programs through City Growers association as well as in organizing training program on urban agriculture and beekeeping.

B) Sargfabrik - Non-commercial, community open-air rooftop garden, organized in form of continuous soil layer over the roof surface, in combination with recreation space on common green roof

The Sargfabrik (former coffin factory) is the most radical experiment within the subsidized housing in Vienna, Austria. Built in the densely built-up district of Vienna, in the period from 1992 to 1994, Sargfabrik was planned by a residents' group; it organizes living by providing strongly variable 'housing boxes' and offers a wide choice of communal leisure facilities, including a restaurant, a sauna, meeting rooms, a kindergarten, as well as extensive green roof. It can be used by all neighbourhood residents and serve as a space for urban agriculture (in the form of urban garden), recreation and leisure (Fig. 3b) Green roof serve also to retain and delay a runoff, provide a close connection with nature, improve biodiversity and air quality, as well as microclimate conditions [24].

C) Autofreie Mustersiedlung - Non-commercial, semi-private open-air rooftop garden, organized in form of raised beds and containers

Autofreie Mustersiedlung in Vienna, Austria, planning since 1994, completed in 1999/2000, is the largest car-free model estate in Europe with building lot size approx. 11.400m^2. The means needed normally for the construction of car parks transferred within this neighbourhood into an environmentally friendly infrastructure that include: greened roof-gardens, parking lots for bicycles, internet-cafe, meeting rooms, children's day-care centre, etc. [24]. A comprehensive ecological concept was realized: low energy consumption level, use of solar energy, a loading station for electric cars, heat recovery from waste water, a grey water system, runoff treatment, green areas with humid biotopes and intensive planting, including green walls and pond. Two roofs are with raised beds and intensively landscaped (Fig. 3c) and serve for urban rooftop agriculture and stormwater management. Additionally, greened roof-gardens provide other multiple benefits such as possibilities for children education, recreation and social interactions. They also improve ecological comfort/microclimate and create healthy and pleasant urban environment.

Figure 3. Urban rooftop agriculture - best practice examples.
a) Brooklin Grange; b) Sargfabrik; c) Autofreie Mustersiedlung

6. CONCLUSION

Urban rooftop agriculture offers opportunities toward urban sustainability, but at the same time these type of specific, building-based urban agriculture and system of food production also have to overcome some challenges. Specific opportunities of urban rooftop agriculture are related to their situation on buildings and technological innovation. In addition to the sustainable use of flat roofs on newly designed buildings, main capacity of urban rooftop agriculture is possibility to optimize the urban space by taking advantage of or currently unused spaces in cities - flat roofs on existing buildings, simultaneously revitalizing these spaces in order to create new urban resources, places for new jobs and environmentally-friendly urban conditions. The use of these already built spaces for food production also reduces the pressure on agricultural land around cities, increases the share of greenery in densely built areas and the level of biodiversity, which is of great interest in the process of urban planning and design. Rooftop agriculture may also become an innovative way of urban agriculture by taking advantage of interaction between farming system and building, in terms of exchanging resource and closing flows, for instance: a) organic waste from the households can be converted into compost to fertilize the crops in soil production, b) water flows (rainwater, wastewater) from the building can be used as a source to satisfy the water requirements of the crops, c) residual heat and CO_2 from the building can be introduced in the greenhouses to improve the environmental conditions and increase the crop yield.

However, urban rooftop agriculture may have to overcome diverse challenges prior to a large-scale implementation, particularly of rooftop greenhouses. It seems that the most significant challenge comes from the fact that rooftop food production is still not included or channeled in the legal frameworks. In that sense, it is important to develop the planning tools that will enable inclusion of these new urban food systems in the urban policy, while ensuring the compliance with urban zoning and building requirements is imposed as imperative. Furthermore, structure of existing buildings can also be a significant challenge - the implementation of farming installation on the existing roofs must ensure the safety of the building structural elements as well as infrastructure, reducing the risks of overloading. Additionally, the complexity of some farming practices (e.g., hydroponics) can also be a potential challenge to develop a local food sector based on urban rooftop agriculture, not only from the economic perspective but also from the availability of trained urban farmers.

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ПОТЕНЦИЈАЛИ РАВНИХ КРОВОВА ЗА ПРИМЕНУ УРБАНЕ АГРИКУЛТУРЕ

Резиме: *У раду се разматрају потенцијали равних кровова за примену урбане агрикултуре, будући да су се као форма и елемент изграђеног окружења показали веома погодним за операционализацију овог све присутнијег концепта одрживог урбаног развоја. Фокус истраживања је на анализи потенцијала различитих типова равних кровова за примену различитих категорија урбане агрикултуре, као и на сагледавању еколошких, економских и социјалних користи на овај начин примењене форме концепта урбане агрикултуре.*

Кључне речи: *Урбана агрикултура, урбана агрикултура на крововима, равни кровови, потенцијал, урбанистичко планирање и пројектовање, користи примене*