

URBAN VERTICAL FARM – INTRODUCTION TO THE SUBJECT AND DISCUSSION OF SELECTED EXAMPLES

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ABSTRACT

The topic of this paper is contemporary architecture of urban agriculture. The aim of the paper is to review the architectural design of vertical farms in cities. The following research methods and techniques were used: literature review, case studies, project descriptions and research by design method. The paper discusses both out-door and in-door vertical farming facilities. Vertical farms can be part of local food systems of cities.

Key words: urban farm, urban agriculture, vertical farm, vertical agriculture

INTRODUCTION

In 1915, the term vertical farming was used to describe a method of cultivating plants on vertical soil walls. Gilbert Ellis Bailey investigated the possibility of such cultivation in craters created after dynamite explosions. The result of his work is a book entitled *Vertical Farming*, which contains a description of the methods, soil properties and how to vertically cultivate selected species of food plants (Bailey, 1915). The origins of

vertical farming can also be found in the use of walls as surfaces for climbing food plants. e.g. fruit trees shaped into a palmette, like peaches walls (fr. *murs à pêches*), (Quellier, 2015).

Currently, the term vertical farm (Rathinasabapathi, 2011; Zeidler, Schubert & Vrakking, 2017; Al-Kodmany, 2018; Waldron, 2018; Appolloni et al., 2020; Butturini & Marcelis, 2020) refers to a objects where vertical farming is carried out – on multiple levels, e.g. on individual floors or using multi-storey grow-

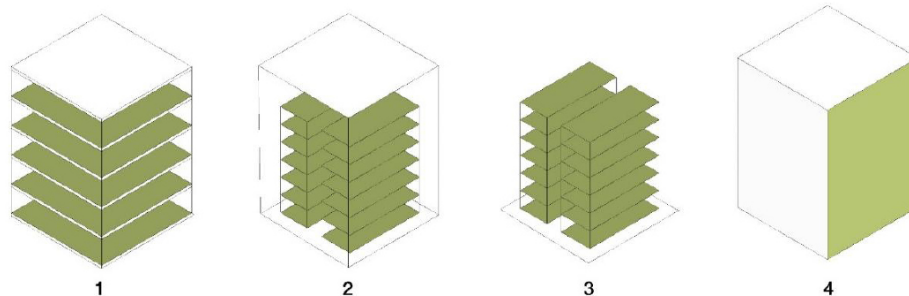


Fig. 1. Diagram of the types of vertical farms: 1 – a building in which floors food crops are grown (in-door farming); 2 – a building with a multi-level vertical farming installation inside (in-door farming); 3 – an outdoor multi-level vertical farming installation (out-door farming); 4 – a vertical surface such as a facade (out-door farming), (elaborated by the author)

ing infrastructure, as well as on the vertical surface of the building, e.g. on a facade (Fig. 1). Vertical farms will differ in the method of cultivation, in-door or out-door farming, and in the method – soil-based or soil-less (hydroponic, aeroponic and aquaponic cultivation methods) (Despommier, 2013; Zeidler et al., 2017; Al-Kodmany, 2018; Rangelov & Staykova, 2020).

OBJECTIVE AND METHODOLOGY

The aim of this work is to review architectural projects of vertical plant cultivation in urban space, including: systematization and description of urban farms, which are a type of the urban agricultural architecture (UAA).

Literature on the UAA has been reviewed in the framework of the study. Selected objects of contemporary urban farms have been analysed on the basis of: architectural drawings, author's descriptions and critical texts published in various sources. Two of presented projects were designed by the author of the paper (research by design method).

OUT-DOOR VERTICAL FARMING PROJECTS

An out-door vertical farm can take the form of a multi-level structure for growing plants or a green wall, such as a facade of an existing building. Examples of conceptual designs of out-door vertical farms in the form of multi-level structures are: the garden structure and the sensory pathway, by Aleksandra Nowysz. The first concept was developed in 2014 for the BMW/Urban/Transforms competition. The installation was based on a repetitive module – a structure of a shipping container. The containers, set on top of each other, connected by industrial stairs, form an openwork structure with an agrarian function (Figs. 2–3).

By multiplying the modules both vertically and horizontally, different forms of multi-level farms can be formed – either as free-standing structures or as additions to existing buildings.

Farm modules can be used to:

- fill in gaps between buildings by continuing the line of the frontage;
- create a second facade – by adding them to the existing elevations, especially gable walls.

Another variant is the container greenhouse, a structure enclosed by transparent walls, e.g. made of glass fibre. In this solution, the farm can have the character of a winter garden, and added to gable wall, would additionally provide thermal insulation.

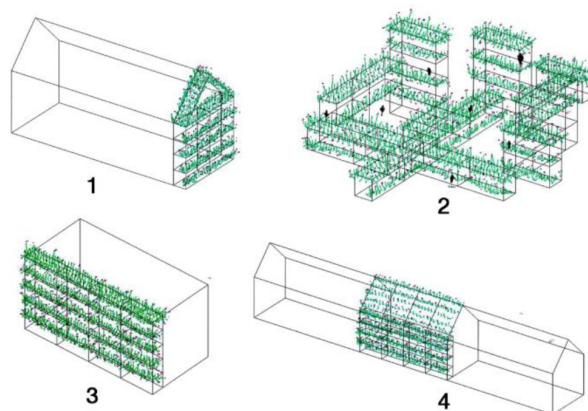


Fig. 2. Diagrams of the garden structure vertical farm variants: 1 – vertical farm adjacent to gable wall; 2 – vertical farm as free-standing structure; 3 – vertical farm as second elevation; 4 – vertical farm filling in a gap in the frontage (elaborated by the author)



Fig. 3. Visualisation of an out-door vertical farm garden structure (A. Nowysz, 2014) – example of a structure attached to an existing gable wall of a residential building (elaborated by the author)

The author developed the second project of a multi-level farm called the sensory pathway during the Open Design School (Matera Basilicata 2019 Foundation, 2019) workshop in Matera (southern Italy). One of the design tasks in the programme was to prepare a concept for the adaptation, for cultural events, of a former quarry Cava del Sole located next to Matera. The city was built from tuff – white volcanic stone. Its oldest historic quarter, Sassi di Matera, is a vernacular habitat on the slopes of a hill, the architecture of which is formed by caves excavated in the rock and added, from the extracted stone, additive in form.

Part of the Open Design School workshop was to develop a symbolic connection between the city centre and the Cava del Sole quarry, a distance of approx. 4 km. The designer proposed to create a modular structure on the road connecting the two places, for the cultivation of plants growing wild in the quarry – herbs with intense aromas (including oregano, basil, lavender). The installation was to create a visual and sensual (associated with the smell) connection between the city and the quarry. Its form was based on a repeat-

ing module – a cubic frame with a side of 0.5 m, in which pots with herbs could be arranged. Placed side by side and on top of each other, the modules form an agrarian structure that can be enlarged vertically and horizontally, thus creating a small architecture along the road (Figs. 4–6).

Both projects, the garden structure and the sensory pathway, are proposals to integrate agrarian infrastructure into the urban fabric. Moreover, thanks to their open form (structures that can be extended in space), these projects also pursue the idea of continuous productive urban landscapes (CPULs), (Viljoen, Bohn & Howe, 2012). These concepts are ideas for revitalisation, e.g. of vacant land or so-called block housing estate, by setting up recreational spaces or adding vertical farms to existing structures, which could be used by the inhabitants.

Another example of an out-door vertical farm is the Public Farm 1 (WORKac, 2008). This temporary installation was created in June 2008 as part of the Young Architects Program (YAP) – annual competitions held under the aegis of the Museum of Modern



Fig. 4. Visualisation of the sensory pathway farm: horizontal and vertical structures for cultivation in urban spaces (elaborated by the author)

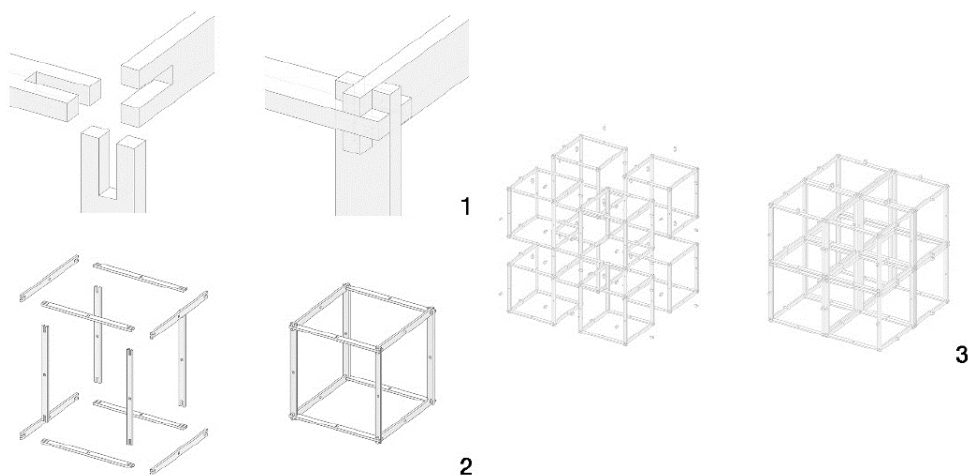


Fig. 5. Structure scheme of the sensory pathway farm module: 1 – detail of connecting wooden profiles; 2 – single module – cubic frame composed of 12 profiles; 3 – structure built of modules (designed by A. Nowysz and T. Schiuma; elaborated by the author)



Fig. 6. Scheme of the sensory pathway vertical farm, assembled from a repeatable module (elaborated by the author)

Art in New York (MoMA) and the MoMA PS1. The task, in one of the regular competitions of the YAP, is to prepare a project for the adaptation of the public space in the courtyard of the MoMA PS1 development. In 2008, the YAP competition was won by the WORK Architecture Company (WORKac), who presented a design for an urban farm, the Public Farm 1. The resulting installation was used both to grow edible plants and to roof a section of the patio. The aim of the

winning project was creating a sense of community around the shared experience of growing food (Public Farm 1, n.d.).

The installation Public Farm 1 is a vertical farm in the form of a sloping canopy, which on one side partially descends to floor level and on the other passes over the walls dividing the interior of the MoMA PS1 atrium, reaching a height of 26.5 m at its highest point. A structure was built using biodegradable or recyclable

materials, such as cardboard tubes. structure is made up of modules of six shorter, suspended tubes around a central, ground-level, tube-column. Each module is designed to grow a different type of plant. A total of 51 different species of herbs, fruits and vegetables were planted on the farm. The empty interiors of some of the columns were used as a bar space, and some of them were also used as a frame for seats. One sleeve has been turned into a periscope, which allows observation of the crops on the roof. The outer surface of the columns has an exhibition and information function. In addition, under the canopy, a poultry house built also of paper material is foreseen.

The installation was built in 49 days, entirely on site. The cardboard form was assembled on a wooden scaffolding, which was dismantled on completion. The paper structure was self-supporting – its walls were screwed together and the fixtures were stiffened with planks. The paper was impregnated against rain and moisture. In addition, the installation was equipped with 18 photovoltaic panels, which were the only source of energy for the farm. An irrigation system for watering the plantation was also provided, with a storage capacity of approximately 22 l of rainwater (Public Farm 1, n.d.; WORKac, 2008).

The MOMA courtyard functioned as an urban farm over the summer and was also a venue for outdoor music events. The project involved local institutions and an international group of 68 volunteers. The Public Farm 1 opened on 20 June 2008 and was dismantled after about three months of use. The vertical open air farm Public Farm 1 functionally and aesthetically diversified the public space. The project was important in social terms because of: the environmental, gardening and food education provided.

Another way of vertical farming is the use of vertical surfaces, as in the case of French fruit walls. The first so-called green walls were created by, for example, shaping fruit trees into palmettes on walls with an irregular and porous surface (Fig. 7). Nowadays various systems of green walls are designed, both in soil and hydroponic technology, primarily having decorative functions, e.g. the green facade of the Musée du quai Branly – Jacques Chirac building in Paris (Blanc, n.d.). However, facades can also be given a productive function by growing edible plants.

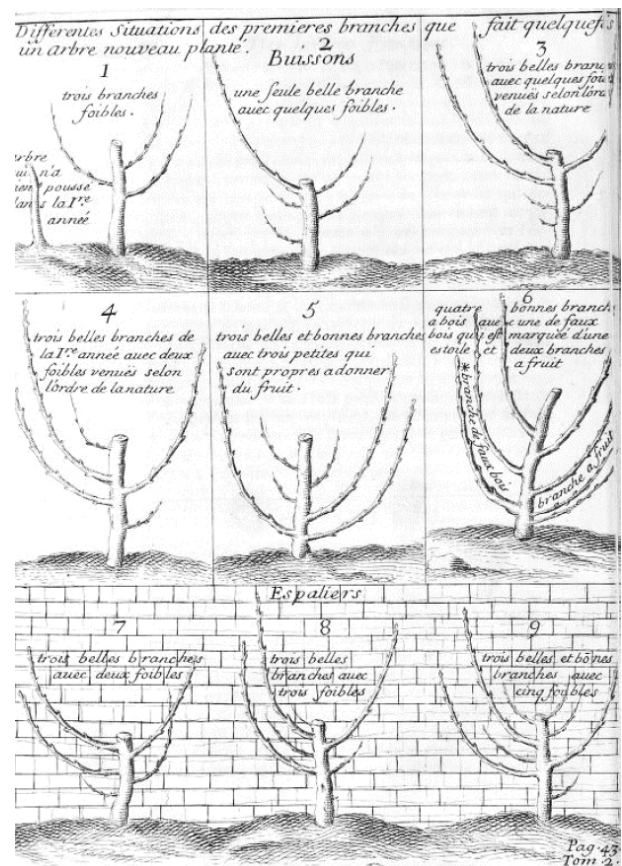


Fig. 7. Figure showing the process of shaping a tree into a palmette (La Quintinie, 1690)

An example of a prototype facade – an out-door vertical farm – is the facade of the American Food 2.0, pavilion designed by the architectural firm the Biber Architects, for the 2015 World Expo in Milan (Biber Architects, 2015). The pavilion is a cuboid hangar maintained in industrial aesthetics. In its interior there is an elongated passage (20 by 30 m) shielded on one side by rooms, and on the other by a double facade: the inner layer of which is formed by a glass facade with a steel structure, and the outer layer – a green facade, which was made in the ZipGrow™ system (used for vertical, hydroponic cultivation of plants), (ZipGrow Inc., 2021). The system consists of rectangular panels with the profile of a pipe, in which water is distributed – delivered to the roots of the plants placed in them. The panels rotate on their own axis, adapting to the exposure of the sun, thus changing the articulation of the facade during the day. The surface area of the green

wall is 860 m², making it possible to grow around 10,000 plants (42 different species of vegetables, fruits, herbs and cereals) at the same time. During the Expo, over a period of six months, the vertical farm was maintained by employed gardeners. The crops harvested five times during this period were used to supply the catering establishments on the site. After the fair the pavilion was dismantled and was to be reconstructed in Hamburg (Biber Architects, 2015).

IN-DOOR VERTICAL FARMING PROJECTS

An in-door vertical farm can be a multi-storey building where food crops are cultivated on each floor, or a one-storey building with a multi-level infrastructure placed for vertical farming. It can either use both soil and soilless cultivation technologies, i.e. hydroponic and aeroponic.

One of the first in-door vertical farms with a hydroponic system are the greenhouse towers: built before 1959 in the Armenian Soviet Socialist Republic (Douglas, 1977) and erected in 1968 in Chorzów (Poland). The latter was designed by Austrian engineer Othmar Ruthner on the occasion of the National Flower and Garden Exhibition. At the time, the structure with a diameter of 11 m and a height of 54 m was the highest building of its kind in the world. The total floor area of about 1,000 m² consisted of movable shelves suspended by chain ties, on which flowers and new vegetables were grown. The entire system was automated and only needed two people to operate it. During the winter, the greenhouse was heated using a gas system. It functioned for 15 years, after which it was dismantled in 1983 due to the darkening of the polyester coating of the walls (Park Śląski, n.d.).

In recent years the topic of in-door vertical farms has begun to be developed by designers. The key issues of the architecture of vertical agriculture were collected by the theoretician – Dickenson Despommier. In addition to food production, he included the cultivation of plants for research purposes, drug production and biofuels. Despommier also developed design guidelines for vertical farms in the urban area (Despommier et al., 2020), i.e.:

- height of approx. five storeys;
- open plan (possibility of different layouts);

- pragmatic floor plan (efficient in terms of food production);
- as much natural lighting as possible (distribution of sunlight in the growing area by means of collector technology concentrating sunlight and diffusion of light inside the building by means of optical fibre technology);
- multi-layered facades made of transparent materials such as ETFE to improve thermal insulation;
- additional lighting with energy-efficient artificial light suitable for growing plants, such as LEDs;
- isolation from external conditions to control the environment (temperature, humidity, presence of micro-organisms) in the growing area;
- equipping the facility with renewable energy technology (e.g. ground source heat pump, burning of biomass, i.e. organic waste from food production);
- the provision of biomass energy technology (e.g. human excreta and organic waste from catering facilities);
- energy recovery – passive system;
- equipping the facility with technology for the recovery of drinking water from grey water (dehumidification system).

A prototype of such an urban in-door vertical farm is a building in the Romainville (Paris) completed in 2021. The vertical farm in Romainville, by Ilimelgo (Ilimelgo, 2018), consists of two rectangular blocks with sloping roofs – the first four and the second seven-storey high. The buildings are connected by a single-storey pavilion containing a common entrance area. All facades and roofs are designed in transparent polycarbonate, thus providing natural daylight. The structural framework consists of reinforced concrete columns and joists and a steel roof truss. The two wings are single-space halls with open galleries on each floor and a central atrium. The gallery areas are made up of 0.5 m high containers filled with plant growth substrate. Between them a narrow passage has been left for the staff. In addition, an extra row of growing pots has been suspended from the gallery ceilings. In the farm, besides plant cultivation, mushroom cultivation and laboratory facilities are foreseen (Ilimelgo, 2016).

The vertical farm in Romainville is a multi-storey greenhouse located in a residential area, in line with

the frontage and in scale with the neighbouring buildings. Its architecture relates to the context of the site – the agrarian function has been integrated into what could be a residential building. This is the first building of this type to be constructed in the city. So far, vertical farms – greenhouses have been built on less expensive land around cities, the Sky Greens near Singapore (a complex of greenhouses equipped with a multi-level hydroponic infrastructure for growing edible plants – mainly different types of lettuce). However, another prototype project, the adaptation of an existing office building into a farm, has been realised before. The building in question is the Pasona Urban Farm in Tokyo (Grochulska-Salak, Nowysz & Tofiluk, 2021).

SUMMARY AND DISCUSSION

Urban farms can be divided into vertical or horizontal, with crops grown inside (in-door) or outside (out-door), and according to the method of plant cultivation – into soil-based and soilless. Vertical farming is more technologically demanding than traditional. Therefore, vertical farming is less common than horizontal farming. Nevertheless, the idea of vertical agriculture in cities is both the subject of theoretical studies and the realization of the first prototypes of vertical farms. These farms are an exemplification of the so-called green architecture, i.e. buildings integrated with greenery. The reason for the development of urban agriculture worldwide is the related multi-faceted social, ecological and economic benefits. What is more, the farms are also used by architects as a distinctive visual accent, which makes them a new form in public space.

Due to the biological function of light in the cultivation process of plants (chlorophyll production), the lighting of the farm is the main parameter determining its architectural form. In-door farms are illuminated exclusively or additionally with artificial light. Out-door farms, on the other hand, only receive natural light. In order to ensure access to daylight, the architecture is optimised accordingly: by situating the building on the plot of land according to its solar exposure, by using as transparent a structure as possible and facades. The interiors are also arranged according

to the conditions, e.g. by using a movable shelf system for hydroponic cultivation, which changes the position of the seedlings in relation to the movement of the sun during the day.

In-door vertical farms with soilless hydroponic technology have been developed to intensify food production and are used in industry. In-door farming allows more control over the growing environment than traditional out-door farming. With in-door farming, the temperature and humidity of the air and the microflora present can be controlled. This eliminates problems associated with flooding, drought, plant diseases and pests. Therefore, the potential advantages of a closed urban vertical farm based on hydroponic technology will include: minimising the impact of weather conditions on crop performance and year-round food production, reduced water consumption (due to closed circulation in hydroponics and aeroponics), greater control over food quality, elimination of pesticides, herbicides and soil improvers and no agricultural pollution (Despommier et al., 2020; Grochulska-Salak et al., 2021). Furthermore, a properly designed urban agriculture system will contribute to food miles reduction and food security of the region where it will be implemented.

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MIEJSKA FARMA WERTYKALNA – PRZEGLĄD PROJEKTÓW

STRESZCZENIE

Tematem artykułu jest współczesna architektura miejskiego rolnictwa. Celem pracy jest przegląd projektów architektonicznych farm wertykalnych w miastach. Zastosowano następujące metody i techniki badawcze: przegląd literatury, studia przypadków, opisy projektów oraz badanie przez projektowanie (ang. *research by design method*). W pracy omówiono obiekty służące pionowemu rolnictwu zarówno na zewnątrz (ang. *out-door farming*), jak i wewnątrz (ang. *in-door farming*). Pionowe farmy mogą być częścią lokalnych systemów żywnościowych miast.

Słowa kluczowe: miejska farma, miejskie rolnictwo, farma wertykalna, pionowe rolnictwo