Vertical Farm: from Agriculture to a New City Architecture

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Abstract
The paper deals with the architectural theme of high-rise construction by cross-referencing it with that of soilless agriculture, recognizing new typologies and critically identifying the strengths and weaknesses of a new relationship between architecture, city and agriculture.
From a disciplinary point of view, the text is organized in four distinct topics. The first part deals with height construction from a theoretical and disciplinary point of view. An excursus identifies in the high-rise buildings a human archetype that today defines certain features of architecture and landscapes in the age of globalization. The second part delves into the subject of soilless agriculture in terms of agronomic technique, with the aim of understanding its origin, efficiency and potential, but also its limits and weaknesses. The analysis is carried out by investigating the production factors at play, such as land, labor and capital, in relation to the revolutions that have characterized the agricultural production sector since the 16th century. The third part analyses three different cases of vertical farms from an architectural perspective because they are alternative to each other and paradigmatic.
The skyscraper model is transformed. Agricultural activity, housing models and aggregated urban functions give rise to complex buildings. The first case is Richard Rogers' 2015 Skyfarm, the second is Carlo Ratti's Jian Mu Tower designed in Shenzen in 2021, the third example is Chris Precht's 2019 Farmhouse. The last part addresses a broader picture: food, cities, social justice, but also urban regeneration, recovery and recycling. Vertical farms are observed from an urban planning angle and considered as a useful element for guiding development and growth in cities and rewriting the relationship between architecture and the countryside. An opportunity to reinvent the multifunctional tall building, open to new ways of living and to redefine the design of the city.

Keywords
Architecture, city, agriculture, high-rise buildings, soilless cultivation, vertical farm

Text contribution: Thomas Bisiani

A vertical history

The tendency to build in height is a characteristic that could be defined as "primary" and which has manifested itself since human beings lived in a nomadic universe. The raising of the menhirs can be considered the first action that defines a "situated object". It is the result of a physical transformation, a "voluntary intention" that, through a change of position, an immediate and intuitive syntactic procedure, transfigures matter from a natural state to the condition of artificial element.

The rotation, from horizontal to vertical, immediately gives the natural object symbolic, religious, geometric and geographical meanings. The erected entity establishes an origin, an element to measure time and space. This simple action, applied to simple objects, is then amplified by its rhythmic repetition, which allows for the development of the complete spatial articulations of the "cromlech" up to great alignments. In Carnac, the system of prehistoric megaliths has a total length of 4,000 meters and is originally composed of over 10,000 menhirs. Verticality represents growth and therefore fertility, the erection of vertical totems in many cultures is the expression of faith in the human being's ability to live in harmony with nature and its divinities.

Human beings continued to build in height, the Great Pyramids of Cheops, the gardens of Babylon, the Lighthouse of Alexandria, all the way to the spiers of the cathedrals, and the towers of medieval cities. The history of architecture is often characterized by the challenge of building in height, fueled by symbolic reasons, not only religious but also economic and political.

For Le Corbusier, in the "Poème de l'angle droit", the ninety-degree rotation connects the world of natural dimensions, governed by the stability of the horizon, with that of the human being, characterized by the verticality of the upright posture. The construction in height is therefore a consolidated figure, which has always been present in the history of architecture and has a highly symbolic value.

Discontinuity – the long century of the skyscraper

In 1896 Henry Sullivan published the famous article "The tall office building artistically considered", introducing a strong discontinuity with the significance of the meaning of vertical construction.

The skyscraper is represented by Sullivan as a completely new type of manufact, as the optimistic expression of the future of technology.

An architectural object that synthesizes in built form, the convergence of different technologies (supporting steel structures, electric light, the lift…) and specialist knowledge. During the 1900, the skyscraper, thanks to this ability to represent the future, has embodied both, the image of the dense metropolis, which grows in height, and its opposite. The skyscraper was in fact also the element around which to construct antiurban visions. This is the case of the prairie skyscraper of the Price Corporation in Bartlesville, Oklahoma by Frank Lloyd Wright. An isolated tower that combined living and office spaces, seen by Wright as "a tree that escaped the forest".

The skyscraper continued to develop in an unrelenting manner until the 1970s. The 1973 energy crisis in particular, begun to underline a series of weaknesses, implicit in the very concept of tall buildings. It is a highly energy-intensive type of building. In fact, much more energy is needed both to build in height and to sustain the building efficiency over time. Furthermore, beyond a certain size, air-conditioned environments are no longer just an opportunity but become a necessary choice.

Once the energy contingency was overcome, however, several health issues remained on the table. The limited availability of natural light, artificial ventilation, the presence in the environment of substances emitted by building materials that have been proven toxic, begun to feed an architectonic culture oriented towards the search for healthier and more sustainable buildings. However, a constructive debate did not arise, but rather radical positions were taken, that have arranged the capitalist interests of exploiting height opposite of cultural opinions of blame and presumption.

Crisis 01

This climate preludes some of the most famous catastrophic representations of the skyscraper crisis. The 1974 Hollywood colossal "The Towering Inferno" stages the burning of the tallest skyscraper in the world during its inauguration, due to the construction materials' poor quality. While "High Rise", novel by J.G. Ballard of 1975, recognizes in the architectural project, the very DNA of the skyscraper, the premise of its demise for having challenged the natural order of things. Modern Babel Towers, contemporary sacred mountains, destroyed due to the same ambition that generated them.

Big and Green

In this complex picture, James Wines recognized a tendency that he has called "Vertiscapes" (Wines, 2002). A sort of ecological design that can become a driving force of architectonic innovation, a form of inspiration for new forms and the future of high-rise buildings. This first generation includes the "green", tall buildings designed by Roger Ferri (New York Skyscraper, 1976), by SITE (High-rise of Homes, 1982), by Emilio Ambasz (ACROS Fukuoka, 1995).

Crisis 02

Twenty years later, the dystopic visions of the 70s have become reality. The attacks on the Twin Towers of September 11th, 2001, have transformed buildings into targets and highlighted the danger and fragility of "extreme" high-rise buildings, seemingly decreeing the failure of the most representative typology of the twentieth century, in favor of suburban scenarios, safer and of higher quality. It was a limited, partial and temporary discontinuity with respect to an evolutionary line of the skyscraper, also considered a "trophy building". New towers have in fact replaced the destroyed ones and the race for growth has not stopped. Contrary to belief, the skyscraper has continued to

be the typology that best represents the most rich and modern urban realities, particularly thriving in Asia.

Crisis 03

The most recent Covid 19 pandemic, which has spread starting from the populous Chinese Cities, has called into question not so much the tall building as an artifact, but rather one of the principles that underline and define its nature and reason for existence: density. It is not yet possible to determine if this could be considered the last, definitive blow to the skyscraper. After more than a century of development and growth, it is not known if these crises will start to develop new alternative typologies, safer and more efficient. Digitalization and dematerialization of the office building will hardly erase the attraction force of the city, as a place of human contact and gathering. It is possible that tall buildings will continue to be built, although different from the contemporary ones, because the search for verticality is a distinctive anthropologic trait that is not possible to erase.

Types and character of Globalization

From optimistic symbol of modern technology, the skyscraper has progressively become a manifestation of financial strength. Globalization has mutated its meaning by effecting one character in particular, dimension (size). Starting from the 1990s, in fact, some considerations were made about the reasoning and consequence of the unstoppable growth trend of buildings. Mario Gandelsonas writes the essay "Conditions for a Colossal Architecture" (Gandelsonas, 1990) and subsequently Rem Koolhaas publishes his famous text on "Bigness" (Koolhaas, 1995). Large architecture, thanks to – or because of – its size, takes on a neutral character with respect to the context. It is one of the characteristics of globalization, indifference towards the specificity of places. Generality and self-referentiality of buildings, whose values reside in measurable dimensions, therefore go beyond any qualitative and merit assessment.

Another typical feature of globalization is the inversion of the relationship between city, architecture and infrastructure. The urban quality of large cities is measured in terms of connections, links, infrastructural equipment, the ability to communicate and build networks with other, equally large cities. Logistics and the interfaces between infrastructures establish needs, forms of value and wealth, but they also define new physical spaces to support material and immaterial flows. These spaces are the result of a new dimension of technology. Technology can be considered the original medium between human and nature. Over time this relationship has grown in terms of complexity. Today the world is facing a third order of technological development, in which artifacts need an intermediate technology to relate to each other, as in the case of the Internet of Things.

The resulting physical spaces are a form of architecture without man, places designed to meet the needs of other entities, where the presence of the human being is limited in time and space. These spaces are developing, attracting the attention of critics and scholars and are evolving, acquiring the dignity of architectural artifacts. Jenny Odell has recognized them by observing the planet from above, through google maps. It is possible to find many similar examples, the Amazon's Robotics Fulfillment Centers are logistic centers where most of the space is forbidden to humans, except for the technicians in charge of robot maintenance. Data centers, "the home of internet", cover thousands of square meters but host only a few technicians necessary for their operation. These are new types, apparently without architectural qualities, where parking is almost unnecessary, where glass surfaces are minimized, as robots do not need light. Fundamentally anti-urban buildings inhabited by things, whose natural location is peripheral, far from the densities of human-inhabited centers.

A first example of building that applies these principals is the robotic intensive warehouse of the Benetton group in Castrette di Villorba, built starting from 1979, designed by Afra and Tobia Scarpa. The production model envisages that garments are made in delocalized factories and the products are all sent to a single warehouse in the Treviso countryside. Managing a single warehouse for an international brand, located in the Veneto landscape, posed infrastructural problems, as shipments to 5,000 international points of sale all depart from this single hub. However, this solution allows to exercise direct control over the products and therefore over their value with the help of only 28 employees.

The 2001 Pig City project, by MVRDV, belongs to a second generation of "architecture without man", which imagines a high-density organic pig farm housed in tall buildings. This model, based on a principle of ecological density, allows to limit land consumption in a country, Holland, where this resource is particularly limited. Pig City not only optimizes the space dedicated to breeding but also poses a "chain" problem, analyzing the needs of processing space and for the agricultural production of forage. The Pig Palace, a 26-storey building recently built in Ezhou, in the Chinese province of Hubei, appears to be less noble in its results. A mammoth intensive farm that, with its 390,000 m2 of surface area, is the largest in China and the highest in the world.

Dark ecologies

Thus, a new relationship between man and nature begins to be traced, in 2007 Timoty Morton coins the term "dark ecology". A dark ecology, in the shadow, but not completely devoid of light. Morton's ecological model predicts that systems are open, linked to each other but with conditional margins, that do not allow for a rigid consequentiality between cause and effect. According to Morton, life prospers precisely in these ambiguous spaces between rigid categories. Conflicting scenarios lead to this horizon, of an open and irregular, indeterminate peri-urban world. The exploration of a new nature, in relation to the human inhabitation and less adherent to an ecological orthodoxy, which becomes for Manuel Gausa black, therefore even more obscure, because it explores those ambiguous environments that typically belong to the periphery (Gausa et al., 2019).

Verticalism

Another trend that characterizes large buildings, is the hybrid character. Their dimension allows to accommodate a variety of functions in their interior. This is a significant feature that calls into question the very origin of the vertical building that in Sullivan's seminal essay was identified with a monofunctional type for offices.

Based on these premises, the building can be developed in height in order to respond to typically urban needs. The city and its complex programs, usually handled bi-dimensionally, can be solved by exploiting a new "verticalism" (Abalos et al., 2011). Multifunctional combinations in height that constitute complete parts of the city, where the articulation of the building's section becomes the equivalent of the ground design for the urban space.

Some risks, greenwashing e biomonotony

On one side, the skyscraper continues to be a current, effective and representative typology, despite the weaknesses linked to sustainability and safety. Current researches are moving towards more efficient solutions and models, aimed at reducing the ecological footprint of new buildings, energy consumptions and favoring natural forms of internal microclimate control. In some cases, these approaches risk turning into "greenwashing"; façade mitigations or compensations, which do not have a significant influence on the environmental impact of these buildings.

Vertical farm

Globalization can be defined as the unprecedented extension of spaces of circulation, consumption, and communication. If globalization presupposes a world without borders, it is possible to imagine frontiers, intermediate spaces, as alternatives, as less defined margins, where differences come into contact and can mix, promoting evolutionary phenomena.

Among these hybridization phenomena, this study focuses on the one between nature and architecture through the typology of the "vertical farm", as it seems to be a form of convergence of different tendencies of contemporary architecture.

On one hand, the tendency towards growth, of which the tall building is a typical phenomenology, on the other, a more recent trend, linked to large buildings, new habitats, functional not so much to host human beings, but rather to be inhabited by "other" agents or forms of life. There is no shortage of sustainability aspects linked to factors of ecological density, reduction of supply chains, reuse of obsolete buildings or abandoned urban areas, reduction of soil consumption and landscape impacts.

All these factors compete to highlight a further, new, profile of the relationship between artifice and nature that characterizes architecture as knowledge. A "para-artificial" nature, unprecedented, contaminated in its development in "hard" contexts. An ambiguous condition, intermediate, hybrid between object and environment, where it begins to appear with some sometimes-disturbing nuances, an architecture with metabolic traits, that seems to begin to "live". The interest of the theme lies precisely in this conflicting condition, of intersection, because it explores those "contact" areas where architectural biodiversity is greatest.

Text contribution: Pierluigi Martorana

Agriculture: from fallow to vertical farm

Agriculture is the main actor in territorial transformations: it manages open spaces and modifies their characteristics according to production needs.

The territory evolves over the centuries in parallel with the development of agricultural activity. The first great agricultural revolution took place at the end of the 18th century. Alongside the introduction of some operating machines (seeder, threshing machine, heavy plough), it codified agricultural rotation, which allowed for a consistent increase in land productivity.

Historically, the progenitor of agricultural rotation is considered to be the Norfolk rotation. It is a four-year rotation (turnip-wheat-meadow-barley) that, together with the introduction of operating machines, determines an increase in land productivity of 30% over 50 years.

The birth of a new cultivation model vs. new landscapes: the closed field

The introduction of new agronomic techniques profoundly transformed the territory. In addition to the progressive abandonment of fallow the disappearance of open fields and collective properties, the formation of closed fields, the reduction of the farm mesh and the introduction of grater crop variability, were also witnessed.

The new production model developed until the mid-1900s handed down the characteristics of the traditional agricultural territory to the present day. In this period agriculture aimed to satisfy the needs related to the sustenance of the farming family and livestock, used both as a food source and as a workforce, with respect to the mercantile component. It was an agriculture where the use of labor prevailed, as the only resource available in abundance, and replaced the productive factors and capital. In the mid-1900s, the second agricultural revolution took place.

Prodromes of an agriculture without soil: towards the revolutionary mercantile model

Agriculture finds itself without resources. In many countries, the number of employees in the sector has significantly reduced: in Italy, for example, in the short period of time from 1951 to 1971 the numbers went from about 8.2 million to 3.2 million, with a reduction of over 60%. The effects of this transformation are enormous: the primary sector is deprived of its fundamental resource (labor), as well as of generational turnover. Not only that: the employees who migrate to industry jobs, go from being producers-consumers of foodstuffs to consumers-non producers, therefore the agricultural sector needs to also ensure food sustenance for this segment of the population. Given the scarcity of manpower, the slogans of the entire productive sector become "crop simplification" and "mechanization": the farming family no longer has the manpower to support a great variety of

crops, nor the internal consumption needed. The crops linked to the sustenance economy were abandoned and the autarkic agriculture was definitively transformed into a mercantile one.

The territory was consequently transformed, often according to the rational use of the machines: the size and regularity of the fields increase; hedges and rows that can hinder the movement of vehicles are eliminated. Productive specialization increases, triggering a trivialization of the territory, the drive towards desertification of rural areas and, from an environmental point of view, a reduction in biodiversity.

It can be said that there has been a replacement of the labor factor of production for the benefit of capital, largely represented by increasingly driven mechanization. The land factor plays an ambiguous role: the overall availability of areas to cultivate does not increase, on the contrary it is eroded by urban development and the abandonment of marginal surfaces, poorly suited to mechanized cultivation. The large companies tend to expand further by purchasing new land: this expansion occurs mainly at the expense of medium-sized farms, while the small companies resist by resorting to subcontracting and family part-time work.

From the gardens of Babylon to the vertical farms

In this scenario, the production technique today generically defined as "soilless cultivation", or "vertical farm" appears and takes hold when conducted in a specialized structure, in a closed and controlled environment, where the production and transformation processes take place. This technique effectively eliminates the land factor of production, replacing it with greater intensification of capital. Landless cultivation is not a recent novelty: it was already known in antiquity, the Hanging Gardens of Babylon for example, and it was constantly practiced in subsequent eras, even if on a smaller scale or on an experimental basis. The first commercial applications were recorded in California in the 1990s and then, towards the end of the century, the technique began to spread in Europe, first in the northern regions and subsequently in the Mediterranean basin.

The most recent evolution of soilless cultivation has led to the differentiation of two large groups in cultivation systems: cultivation systems on substrate and cultivation systems without substrate.

In the first case, the plant has a certain volume of substrate available which guarantees the anchoring of the roots, as well as a water and nutritional supply which reduces the causes of risk in the production phase.

The substrates used can be of organic or inorganic nature, but in any case, they only have a support function and do not contribute to plant nutrition. They are mainly differentiated, according to their water holding capacity, into fibrous substrates (for example straw, coconut fiber, rock wool) and granular substrates (such as sand, perlite or expanded clay). Plant nutrition is ensured by an irrigation system that delivers a fertilizing solution, usually through drippers. More recently, and especially in "vertical farm" plants, cultivation techniques without substrate have established themselves, they are systems that do not involve the use of organic or inorganic materials for anchoring the roots of plants.

The most used of these techniques is NFT (Nutrient Film Technique) hydroponics: a thin layer of nutrient solution flows inside channels where the plants are placed in such a way to have the root system partially immersed in the liquid.

A second type of hydroponic technique is represented by the "Floating System", where the plants are supported by high-density polystyrene panels that float in tanks filled with nutrient solution.

Finally, aeroponic cultivation must be considered, a technique that finds application on species with limited growth, such as lettuces, strawberries and some flowers. The plants are supported by plastic material panels, arranged horizontally or on inclined planes and anchored to a support structure, to form a closed box with a rectangular or triangular section.

All the techniques listed highlight, as a common factor, the characteristic of being freed from the agricultural land as a source of support and nourishment for the plants.

From the gardens of Babylon to the vertical farms

If these technics are implemented by traditional structures, like greenhouses and tunnels, a particularly significant saving in land consumption is not achieved, this is because plants need to occupy the necessary space for their development anyway. In order to evaluate the actual saving in land consumption it is necessary to consider that, compared to a cultivation on farmland, soilless agriculture allows for faster productive cycles and a higher productivity: the comparison then, has to be conducted calculating the obtainable production by year and by surface unit invested and comparing this data with the same parameter calculated by the obtainable production by traditional techniques.

The most evident advantages of soilless agriculture involve the reduction in consumption of water resources, that in hydroponic agriculture is of about 90% and in aeroponic it can even be higher than 95%. Furthermore, it results in the obtainment of a healthier product, because of the presence of a more controlled environment and the absence of contact between plant and soil limits the presence of pathogens and so reduces in considerable measure the necessity to use pesticides.

The reached significant advantages in terms of soil consumption are linked to a further sophistication of the production process, that implies the control of the microclimate and of its environmental parameters. Natural light is substituted by LED illumination that reproduces solar radiation; the air is treated with filtering systems that don't allow the diffusion of pathogenic microorganisms and fungal spores; the temperature is controlled through conditioning systems. These characteristics can also be obtained inside dedicated structures, that allow the organization of agriculture on a series of stacked floors or on vertical walls; they also lend themselves to robotization of various operations of the productive cycle that leads to a drastic reduction in the need for manpower.

Advantages and disadvantages of vertical farms for the future of urban agriculture

Ultimately, the vertical farm makes it possible to effectively release the production of agricultural commodities from the consumption of the soil: the dedicated spaces are reduced to the site of the structure that hosts the process and these spaces do not necessarily have to have an agricultural purpose or be made up of agricultural land. A scenario of great interest opens up in terms of urbanization of agriculture or, at least, of some agricultural sectors: new production structures can be built within the urban fabric, or abandoned buildings, previously used for other activities, can be recovered. In both cases, the advantage obtained is closeness between production and consumption, with clear benefits in terms of transport flows, logistics and organization of the supply chain of the products produced.

The trend towards urbanization of agricultural cultivation and, consequently, towards the simplification of the chain linked to the distribution of products, acquires particular interest in the case of large residential agglomerations, where the contiguity between production and consumption translates into a substantial saving of resources for the community.

If the described picture highlights a series of positive aspects, some critical issues concerning the application of production techniques related to vertical farm cannot be overlooked.

It must be observed that these techniques require very high investment volumes, above all, if a high level of automation of the process is planned. The necessary investments concern all phases of the process, from the construction of the structures to the hardware control and software management systems. The installation and fine-tuning of the control systems of the environmental and microclimatic characteristics are also necessary and, finally, highly specialized personnel must be found and trained, not only able to follow the development of the crops from a strictly agronomic point of view, but also to govern the complex mechanical systems that operate within the structure.

Finally, it should not be overlooked that the operation of the machines, as well as the maintenance of the environmental and climatic conditions inside the structures, require a substantial expenditure of energy. Optimal levels of temperature, humidity and lighting must be maintained; to prevent parasitic attacks, it is necessary to install air filtering systems that prevent the entry of pathogenic microorganisms and fungal spores.

Vertical farm, a real revolution?

In the general context, the vertical farm is often considered the new agricultural revolution, but this interpretation probably needs to be scaled down. It is undoubtedly a management model that frees production from the availability of land and allows supply and demand to be physically brought together, transferring the production function within the urban context. However, this is a model limited to specific production sectors, such as horticulture and nursery gardening; the space saved by moving these productions to the cities remains available and is used by traditional agriculture, which manages it to cultivate the arable land and tree species characteristic of the other production sectors.

Perhaps the real revolution underway, intimately linked to what happened in the 1900s, is represented by an increase in intensity of capital in the production process, which manifests itself with the adoption and use of increasingly sophisticated automation systems (the so-called "Farm Bots"). In this sense, remaining within the classical macroeconomic categories, the productive factor replaced by the greater capital intensity is not land, but once again labor.

Text contribution: Adriano Venudo

Involution, evolution and revolution introduced by vertical farms. Case studies and "leaps of species".

The proposed cases are paradigmatic because if seen together, they prepare for the leap of typological species, like it was for Sullivan's first skyscraper and mega-structuralist experiments of the 60s.

The vertical farm could represent a sort of "urban revolution" because it would bring factories back to the city, reinserting production within the urban fabric and the city's architecture, obviously with expectations and "effects" or impacts that are completely different from nineteenth-century industrialization of some cities.

The vertical farm is an interesting phenomenon to study because it integrates agriculture into the form of the city and contemporary architecture, a new type of agriculture. It hybridizes typically extra-urban soil and materials with urban ones, the typology of the skyscraper becomes the vector of a new urban form.

These three cases show different levels of transformation of the skyscraper into a complex urban structure: from the "simple" one: Rogers' Skyfarm, where the skyscraper is a real monofunctional vertical farm that only includes functional and public relations in the base with the city; to the Farmhouse in Precth which, although it only has spaces open to the city on the ground floor, it introduces forms of semi-public space shared between the apartments on the various floors, as well as being an experimental model of a vertical agricultural community; to reach a more complex and hybrid model, Ratti's Farmscraper that also includes public spaces inside, on the various floors, and mixes the agricultural production unit with other functions, giving rise to new "agro-urban spaces…".

These three cases are examples of different and possible aggregation models and combinations of the vertical farm with architectural and urban functions of the traditional skyscraper: on the one hand the centralized farm combined with a set of other functions, and on the other the farm from the sum of many small production centers corresponding to the individual residential units.

The results? Similar but different. Definitely something new to investigate.

Innovative architectural conformations also correspond to these two vertical agricultural models which translate the different functions into the "skyscraper shape" both at a purely compositional level and at the level of architectural language, but above

all translate the "skyscraper shape" into new functional, perceptive, connective, social, economic and of meaning relations between architecture and the city.

The proposed consideration on the skyscraper is that it becomes vertical farm, but also becomes a new social model: it is the birth of "vertical urban agricultural communities". It also becomes a new urban item, genetically modified, just as it has been since its first appearance in cities. When it began to spread at the end of the 19th century, it soon became an urban icon and the new vertical architectonical model was transformed into an economic symbol, into a social scheme, into a status and finally into a cultural phenomenon. The architecture that stratified vertically, condensing the city one floor above the other, marked the paradigm shift. The way of thinking and seeing architecture and experiencing the city changed. Perhaps today it is possible to say that the modifications, transformations and mutations that vertical farms induce and will induce in the traditional skyscraper (and in agriculture), will certainly produce something new and disruptive, similar to the leap of species… not just typological? Perhaps yes, because the skyscraper is also and above all a "cultural fact".

Case study 1: Skyfarm

This is a prototype of a vertical farm, which can be applied to different urban and environmental contexts and on different scales of intervention, developed by Richard Rogers (RSHP) as a research project for the 2015 Milan Expo "Feeding the planet". It is designed according to the standard agricultural factory model, redesigned however, on the vertical farm and then developed over the typology of the skyscraper. This skyfarm model elaborated by Rogers presents various possibilities of applicability, adaptation and flexibility.

It is a "pure" vertical farm, entirely dedicated to indoor agricultural production, conceived as an architectural machine. The functional and architectural concept stems from the assumption that by 2050, 80% of the world's population will live in cities. It is therefore essential to think about alternative agricultural methods to the traditional ones on land and in the open field to feed the inhabitants of the city, and at the same time it is also necessary to identify methods with low impact of emissions and low use of energy. These assumptions inevitably lead to think about urban agriculture and the possible forms of integration with the city towards the self-sufficiency of buildings, not only in terms of energy, but also in terms of food. The vertical farm is a possible answer because it satisfies both needs. Rogers' Skyfarm – RSHP is a skyscraper almost entirely dedicated to agricultural production, and only a small portion is dedicated to the public and to commercial, recreational and hospitality activities.

The tower develops an interesting structural scheme, a hyperboloid, which can take on different scalar variations in relation to the morphological conditions of the context, and the façade solutions could be different in relation to the climatic sunshine conditions of the site. This vertical farm offers a wide and diversified crop production, but also a hybridization of the types of cultivation, a principle which is also at the origin of the formal and structural choices.

The multi-floor tensegrity structure (compressive isolated components outlined by pre-stressed tension elements) is designed in light bamboo in order to build a rigid but slender circular structure (hyperboloid), maximizing the sun exposure of the mirrors on the "interior fields" of cultivation.

The hyperboloid shape of this skyscraper allows for easy scalability. In fact, the model allows various alternatives: from versions that can be installed in medium-small cities, to versions for denser urban areas. The particular hyperboloid geometry adopted can be easily altered also in relation to the terrestrial latitude and the amount of sunlight available.

This vertical farm supports various layers of agricultural cultivation and an aquaponic system which allows the growth of vegetable crops and fish together, according to a system of recirculation and mutual collaboration: the nutrients derived from fish waste feed the plants as a filter for fish habitat. The main production derives from hydroponic cultivation inside a large tank placed above the entrance base, which also gives stability to the structure and which is counterbalanced by a tank placed on the top. The tank above the public entrance spaces is also used for integrated fish farming with hydroponic crops. The tank at the top, which is transparent and lets the light pass to the floors, collects rainwater that is used for freshwater fish farming. The floors between these two tanks instead, house the spaces for pure hydroponic and aeroponic cultivation. The energy self-production systems are installed on the top: wind turbines and mobile solar panel systems.

The structure is divided into vertically layered "productive zones" to make the best use of water and nutriments, and to efficiently distribute the weight of the water across the supporting skeleton of the tower. The particular hyperboloid structure obviously determines the shape, but also the treatment of the façade texture, becoming a synthesis of the productive-agricultural, architectural-functional needs and also of formal linguistic expression.

The only spaces open to the public are located on the ground floor: a market, a bar and a restaurant that use the products of the vertical farm, a visitor center with an exhibition and an educational space, a social center and a covered square. This covered square, located at the center of the commercial activities, is a large full-height void that makes the entire structure, the various activities and the machines for this new urban agriculture, visible. The tower has a very high technological content, which is clearly visible in the shapes, spaces and architectural language.

Case study 2: Farmscraper

The Jian Mu Tower is an experimental skyscraper that hybrids different functions and spaces, integrating the vertical farm with other urban activities. It is a skyscraper designed by Carlo Ratti along with Italo Rota (structures by Arup and Hydroponic Farming System of the Zero society) in 2021 for the Wumart chain in Shenzhen, a Chinese metropolis of over 12 million in-

habitants close to Hong Kong, in one of the most densely populated areas of the world. It will be a 51 storey building, 218 meters high with a very articulated functional program that not only foresees indoor cultivation but also the transformation of the raw materials and their sale, residential units, offices, grocery stores, shops and public spaces. The skyscraper will occupy the last free block of the business neighborhood of Shenzen and for this reason it is also a great opportunity for the urban asset and dotation, social life services, and for its architectural role in the city skyline. For this reason, it will not only be a "tall building", but a real piece of the city with many functions, social values and economic implications. The surplus value with which this architectonic and urban theme develops is precisely in the typological integration of the "classic skyscraper" with that of the agricultural farm and urban agriculture. The driving agricultural typology will be the hydroponic one (vertical hydroponic farm), to which one eighth of the skyscraper surface will be dedicated. A further quantity, about 10.000 sqm, will be dedicated to microcultures diffused on various floors, but with differentiated modalities of cultivation. These further diffused cultures inside the tower will be integrated with other spaces and hybridized with other activities, like for example the vertical green houses on the façade or the citrus groves in the halls, the food court, introducing this way an almost new idea of "widespread vegetable garden" integrated with the common and distribution spaces inside the tower.

The estimated food production of this vertical farm will be of 270 tons per year, covering for the needs of about 40.000 people. This agricultural-architectural model configuration will create an urban self-sufficient food chain that will manage the cultivation, harvest, sale and consumption within a single building, which will contribute to save a lot of energy for the distribution and logistics of the food. All of the production will be managed by a "virtual agronomist" supported by artificial intelligence that will regulate the daily agricultural activities (irrigation, environmental control, nutrition, harvest, etc…). This is a sort of adaptation of the traditional robotized hydroponic farm model to the vertical façade model of the tower building.

The shape of the skyscraper will refer to an ancient Chinese philosophy of Tian Yuan Di Fang – "round sky and square earth", where the base of the tower is rectangular, and the top is cylindrical. The architectonic and compositive development of the skyscraper then is a complex volume that arises from the gradual transformation from a solid with a square section to one with a circular section ("loft" solid). According to this logic of formal complexity, the facades are spaces. They are inhabited diaphragms that contain the greenhouses and the vegetation (which also function as a climatic autoregulation for the building) and thus characterize the architectonic language and the urban facades of the tower. The vertical development is also highlighted by the five "loggia floors" (about one every 10 floors) that contain gardens, vegetable gardens and common spaces. These "loggia floors" are composite nodes because they mark both, the outside and the inside of the building: they overlook large internal halls, winter gardens on several levels, onto which offices, commercial spaces and the common terraces open. They are therefore architectonic devices that not only guarantee the necessary space for vegetation and cultivations, but they constitute the internal spatial continuity, characterizing at the same time also the compositive development of the skyscraper. The space necessity for indoor agriculture becomes the compositive principle of the tower and also of the characterization of its architectonic language.

Case Study 3: Farmhouse

In some way, indebted to the idea of Le Corbusier's Immeubles-villas for the distributive articulation, in 2009 Chris Precht's studio designs a vertical farm that proposes a complex scheme of a modular aggregation system on a tower typology of residential units, each one integrated with a private productive portion. It is a sort of highly specialized vertical vegetable garden connected to the residential units. This "agricultural space", integral part of the accommodation, has been sized and designed to produce and satisfy the food needs of the tenants of each housing unit. The base model for the project then is very different from the "traditional" vertical farms, experimented in the metropolis. The skyscraper is not a single central farm, but a collection of many small gardens. They are many small specialized productive centers that utilize and combine different agricultural techniques and technologies in order to satisfy micro-needs. This produces an overall productive surplus which is collected, possibly exchanged and shared among the tenants or sold in a fruit and vegetable market located on the ground floor of the skyscraper, in the entrance hall, which also serves as a square and public space. The principle a self-sufficient system made up of the sum of many small autonomous production centers, the farm-apartments, which obviously provide for a particular lifestyle, the tenant also becomes a farmer and is part of an urban farming community: The Farmhouse. It is an agricultural community that lives vertically. Also in this case, the places of production, transformation and consumption coincide, because they remain in the same tower, reducing impacts, costs and emissions do to the transformation and transportation of food.

The tower is modular and flexible in terms of height. It is designed for the large Chinese metropolis, but also for the medium-small European cities.

The tower is constructed with a prefabricated system of housing modules in laminated wood with an "A" shaped structural scheme. The module is designed to allow multiple joints and flexible combinations both in plan and in section according to a very free system that allows to stack more modules on top of each other and to develop the apartments as duplex. Every duplex has an open plan living room and kitchen on the first floor, with tent shaped bedrooms on the upper floors. The duplex aggregation system allows to optimize the common access spaces on every two levels. By aggregating empty spaces on the external edges, every residence has its own balconies available to cultivate the common central nucleus both towards the outside, on the façade and towards the inside. These empty modules,

the "agricultural balconies" are equipped for traditional agriculture with soil, therefore in pots or tanks or even for hydroponic techniques. The balconies also have a rainwater recovery system, a system of solar panels and micro wind turbines to meet the energy needs of each unit. This aggregation makes both the internal and external spatial articulation of the tower very complex. The combined interlocking modules build a very unitary whole that works on the structural principle of the diagrids and on the compositional principle of the "filled trellis", recovering the capsular architecture of the Metabolists of the 60s.

In addition to the production modules, the aggregation of a garden module is foreseen for each accommodation, which is an external green space. On each floor there will also be common ones. These private and common gardens are V-shaped buffer zones between the apartments, because they derive from the interlocking, inverted spaces left free between the modules. These common modules pierce the body of the tower, opening up views and letting light and air pass through this complex three-dimensional grid, indispensable condition for plant nutrition and growth.

This construction system is also flexible in height and can vary from 18 to 30 floors.

Besides the public spaces and the market on the ground floor, underground cellars are planned for the more perishable fruit and vegetables, for the storage of seeds and for the common composting of waste, which is then reused as fertilizer for the vegetable gardens throughout the Farmhouse.

Text contribution: Sara Basso

Vertical farm, food and the city: rewriting the relationship between city and countryside

The attention of the urban discipline for the vertical farms inserts itself in the broader and bigger debate that rewrites the relationship between food and city, more specifically, it is one of the possible solutions to address the problem of food security (Al-Kodmany, 2018; Despommier 2010). To date, it seems difficult to achieve objective 2, "zero hunger" of the Global Goals (GG) established by the 2030 United Nations Agenda. Pursuing this objective requires acting on several fronts and implementing multidimensional policies and projects, which intervene both on the food, environmental and welfare systems, as well as on people's styles and habits (Willet et alii, 2019; HLPE, 2022; FAO 2019).

Within this framework of conditions, the city continues to remain a privileged field of intervention for policies and projects aimed at achieving the sustainability objectives indicated by the GGs (Sonnino, Tegoni & De Cunto, 2019). The reasons are clear: today, 55% of the population lives in urban areas and this percentage is expected to increase by 2050 (FAO, 2019). Furthermore, cities consume about 80% of the total energy produced globally and produce 70% of the global waste: overall they absorb 70% of food resources . If "feeding the city" becomes an imperative, it becomes equally important to understand how this can be achieved by guaranteeing sustainability of food systems and, at the same time, a more general and widespread right to food (Rodotà, 2014).

Food and city. Is the vertical farm a possible answer?

Since the beginning of the new millennium, the need to consider food as a theme of urban planning and urban design has been recognized (Viljoen et alii, 2015; Viljoen, Wiskerke, 2012; Lohrberg et alii, 2016). From a design perspective, this has involved efforts to reconfigure the boundary between urban and rural as a generative place for activities and practices aimed at reapproximating city and countryside (Donadieu, 1998; Mininni, 2012). Widely debated is the role that agriculture can hold in redesigning the urban borders, recovering abandoned places and buildings, regenerating and enhancing natural forms in the city. It is, in the multiple forms of urban and peri-urban agriculture that it is possible to recognize the potential to make agricultural production systems more sustainable and cities more resilient (de Zeeuw, Drechsel, 2015; Mougeot 2005). Urban projects that include traditional forms of agriculture can improve the ecological conditions of urban spaces, contribute to guarantee the health of inhabitants, contrasting social inequalities (Basso, Di Biagi, Crupi, 2020; Marino et alii, 2020).

Looking at the European context, the debate on forms of intensive urban and indoor agriculture, free from the land factor, that utilize height density as a productivity aspect, appears less evolved. With the exception of some more famous proposals –like PIG City by MVRDV (2001), or Tour Vivante by SOA Architects for Plateau Saclay (2006), in the Parisian periphery – The debate on vertical farming (vertical Farm) as an opportunity for reflection on the urban form, still appears weak, perhaps also undermined by the contradictory results of experiences in the more mature Asian and American contexts.

The recovery of an old but still good idea

The idea to integrate nature into building typologies that develop in height is obviously not new. The disciplinary references are widely known and discussed: from the hanging gardens of Babylon to Le Corbusier's Immuebles Villas of the 1920s (Al-Kodmany, 2018; Sommariva, 2014), there are several projects that have tried to replicate productive nature inside towers or high-density typologies. These are examples that prelude the more recent efforts to combine agricultural production with the extreme symbol of urban technological modernization and efficiency, the skyscraper. However, it is possible to observe, especially in the more well-known and recent experimentations of vertical farms, how the building can still be isolated, or, not be able to relate to the urban fabric, unable to generate a settlement principle capable of rewriting the form of the city. One wonders: can vertical farms really integrate in urban fabrics generating new habitable spaces and at the same time, answer to the food needs of the city?

Vertical farm as an urban issue: socio-spatial justice and city design.

It may be helpful, from an urban planning perspective, to better articulate the consideration on vertical farms on points that intertwine themes of food production in the city with issues of

social justice and public health.

A useful premise to better frame the vertical farm as an "urban question" should be made recalling how the issue of food safety has progressively refined into "nutritional security" (FAO et alii, 2018). Helped by the theories of Amartya Sen (1981), "accessibility of food" has today been attributed an increasingly significant weight. Food security and foodability are concepts that redirect to a food accessibility concept that keeps into consideration, besides the physical distance from the places of food production and distribution, the economic conditions of the users and their individual ability to recognize and obtain healthy and appropriate food (Rodotà, 2014), and that the environment where people live allows them to live a health lifestyle. This conceptual shift is significant, because it transfers attention from food to the context in which it is distributed, consumed, recycled. It is not a coincidence that the themes of food and nutritional security have intertwined with those of the healthy city (de Leeuw, Simos, 2017; Dorato, 2021), where the entire urban space is called upon playing a decisive role in ensuring accessibility to food in environmental conditions favorable to human care.

Read through the issues of food safety, the right to food and public health, vertical farms show some limitations. They seem to respond, at least partially, to the issues brought forward by accessibility of food, by bringing food production to the city in intensive forms, independent from the availability of the land factor. Vertical farms are, to all intents and purposes, among the forms of urban agriculture; however, the highly entrepreneurial nature of the initiatives underlying this activity, and the risks it entails, make it difficult to recognize, at least at the moment, its social potential.

This is because of some critical factors linked to the cost of technology, to the high level of specialization that affect the production costs and as a consequence, the cost of food, making it less accessible (Butturini, Marcelis, 2020; Despommier, 2020; Steel, 2021; Stringer et alii, 2020).

The absence of the land factor in this type of production is, from a social perspective, a further critical element. Indeed, it is clear that in a context like that of the vertical farms, what is missing is contact with nature, in its authentic dimension, or rather, it is re-proposed in a technocratic emulation.

Further considerations can be made if one looks at the agricultural production spaces as elements of the urban composition or, in other words, of the city project. The urban and periurban spaces within which agriculture has been practiced, have always represented an important "material" through which to compose the city or its parts. It is possible to think, for example, of the fundamental role that spaces and places for the production and preparation of food played in the twentieth century in improving people's living conditions. From family gardens in working-class neighborhoods to the functional kitchen in Frankfurt, "food spaces" have been seen as areas of experimentation for research into living space and public housing (Di Biagi, 2016; Panzini, 2020; Parham, 2020). A theme, that of the relationship with the context, which could open to reflections and experiments useful for rethinking the typology of the vertical farm in new forms where, the attachment to the ground can be reconfigured as a space of mediation with the city.

The vertical farm as an occasion for urban regeneration, between recovery and recycle.

Instead of liquidating Vertical Farms as too bold or controversial a solution, to address the issue of food production in the city and, more generally, that of food security, it is important to try to understand the possible way forward to make this solution feasible in order to "feed the city", besides being a design innovative field for new skyscrapers.

It is important to specify how the vertical farms represent a large category of urban agriculture; some authors, including Despommier (2010) himself, propose to distinguish at least three typologies of vertical fam: the first foresees the use of controlled buildings of different heights with exclusive farming functions, that can derive from the reconversion of abandoned buildings; the second which involves the reuse of old and new buildings' roofs; and the last typology, the one that imagines indoor forms of agriculture inside visionary buildings with multiple floors (various proposals have been designed but none have been built). In synthesis, these are three typologies that make way for the "skyline farm". Making this distinction is important because it allows to individuate possible strategies of intervention in order to mutate the image of the city and relate to its design.

This distance between visions and realizations offers however, the opportunity to think about the idea of the vertical farm, not only as a simple building developed in height but as a more complex food infrastructure, shifting the attention from the skyscraper machine to its ability to spark virtuous relationships with the urban context, first of all in rethinking the design of the city in the prospective of regeneration and urban metabolism (Gasparrini, 2016; Grulois, Tosi, Crosas, 2018; Dal Ri, Farvagiotti, Albatici, 2020).

For this reason, those examples where the birth of indoor agricultural forms is accompanied with recovery of abandoned buildings and with more complex urban regeneration processes, appear to definitely be more interesting. The Plant, for example, is a vertical farm that takes up residence is a building that was once dedicated to the aging of meats in the meatpacking district of Chicago (Despommier, 2020). Besides the productive diversification (fish are raised, beer is brewed, Kombucha is produced and mushrooms are grown), what appears to be interesting is the attempt to make everything sustainable, through recycling trash, even that of surrounding establishments, thanks to a biogas anaerobic digester . The involvement of small local producers in the yearlong open market appears to be urgently important, just like the commercial activities related to kitchens, breweries etc… In conclusion, the numerous activities are

[1] *Cfr. https://www.fao.org/green-cities-initiative/en*
[2] *https://www.archdaily.com/231844/the-plant-an-old-chicago-factory-is-converted-into-a-no-waste-food-factory*

what makes the operation "sustainable", the idea that the vertical farm is an element of a more complex "social condenser" based on "sustainable" agricultural forms.

In the wake of this and other experiences, it is possible to obtain some elements to reflect on the design of "vertical farms" that reorient the design of the city.

The first consideration is in recognition of contexts like the European one, where the most plausible typology of vertical farm to be included inside the city is the one that points at the recovery and the recycle of discarded containers and/or abandoned areas. The vertical farm can then, become the spark to more complex operations of regeneration for abandoned areas, like in some places, even in Italy, efforts have begun to be made .

A second consideration is the possibility for vertical farms to enter in synergy with, rather than compete with, more traditional forms of agriculture. The modalities to construct these synergies are different. It is possible, to think of the vertical farm as a system of trash and waste recycling for agriculture businesses (and maybe even cities), just like in The Plant. This could be a way to make vertical agriculture part of the urban metabolism, with an active role in configurating urban and agricultural cycles in a sustainable way.

Some experiments, even in less mature contexts like the Italian one, deal with this theme. The project Team PineCube, for example, involves the recovery of an old school in Orzes (Belluno), through vertical agricultural production that introduce water recycling. The objective is, in this case, to grow niche products to support agriculture in innovative forms, without forgetting about the possibility to involve fragile and/or disadvantaged subjects (Colucci et alii, 2020; Orsini et alii, 2020). From a design point of view, this recalls a multifunctionality of buildings that still allow many margins of experimentation within the typology.

Lastly, a final argument, related to the previous one, concerns the ability of the vertical farm to trigger transformations able to favor more structured forms of relationships with the urban context through agriculture. The reference, in particular, regards all those induced activities related to production, but also to education, sale, consumption of food, even to research. A theme that also, calls into question the project of the "level zero", or ground relationship, of the vertical farm, that can be thought of as "space of connection" and mediation between the buildings themselves and the context (Dal Ri, Farvagiotti, Albatici, 2020). The challenge for the project of the vertical farm is open, and it presents itself as an opportunity to reinvent the multifunctional tall building, open to new ways of inhabiting, and the project of the city.

Translation: Arch. Vittoria Umani

[3] *In Veneto, the Ri-Genera project promoted by Enea will target decommissioned warehouses and abandoned buildings such as barracks and roadman's houses by creating vertical greenhouses for hydroponic cultivation, that is soilless, which will guarantee a greater production of vegetables with minimum water consumption and without the use of pesticides: https://www.enea.it/it/vertical-farm/la-vertical-farm-enea/la-vertical-farm-negli-edifici-dismessi-arkeofarm*

References

Al-Kodmany, K. (2018). *The vertical farm: A Review of Developments and Implications for the vertical City*, Buildings, 8, 24. doi:10.3390/buildings8020024

Basso S., Crupi V., & Di Biagi P. (2020). *Downscaling Food System for the 'Public City' Regeneration. An Experience of Social Agriculture in Trieste.* Sustainability, 14, 2769.

Abalos, I., & Grau, U. (2011). *Verticalismo. The future of skyscraper.* In A. Fernandez Per, J. Mozas, & J. Arpa, This is Hybrid: an analysis of mixed-use buildings by a+t. Vitoria-Gasteiz: A+T Architecture Publ.

Butturini, M., & Marcelis, L.F.M. (2020). *Vertical farming in Europe: present status and outlook. In Plant Factory An Indoor vertical farming System for Efficient Quality Food Production.* Kozai, T., Takagaki, M., & Niu, G. Eds. Amsterdam: Elsevier.

Colucci, N., Dall'Agnol, N., De Biasi, P., Orsini, F., Tagliaferri, N., & Tonet, E. (2020). *PINECUBE: technologies for sustainable plant production and urban renewal in Belluno (Italy).* Acta Hortic. 1298. ISHS 2020. DOI 10.17660/ActaHortic.2020.1298.20

Dal Ri, S., Favargiotti, S., & Albatici, R. (2020). *The role of vertical farming in re-thinking and re-designing cities within a circular perspective.* Tema, Vol. 6, No. 1. DOI: 10.30682/tema0601i

de Leeuw, E., & Simos, J. (2017). *Healthy cities: the theory, policy, and practice of value-based urban planning.* New York, NY: Springer.

de Zeeuw, H., & Drechsel, P. (2015). *Cities and Agriculture. Developing resilient urban food systems Food and Agriculture.* New York: Routledge.

Despommier, D. (2010). *The vertical farm: feeding the world in the 21st century.* New York: Picador.

Despommier, D. (2020). *Vertical farming systems for urban agriculture in achieving sustainable urban agriculture.* Wiskerke, J. S.C. Eds. Cambridge, UK: Burleigh Dodds (pp. 143-171).

Di Biagi, P. (2016). *Cibo, spazi, corpi. Spunti per una riflessione sull'abitare quotidiano nella città pubblica, e oltre.* Territorio, n. 79, pp. 53-59.

Donadieu, P. (1998). *Campagnes urbaines.* Arles, Versailles, France: Actes sud École nationale supérieure du paysage de Versailles.

Dorato, E. (2020). *Preventive Urbanism. The Role of Health in Designing Active Cities.* Macerata, Italy: Quodlibet Studio.

FAO (2019). *FAO framework for the Urban Food Agenda.* Rome.

FAO, IFAD, UNICEF, WFP, & WHO (2018). *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition.* Rome. FAO.

Gandelsonas, M. (1990). *Conditions for a Colossal Architecture.* In Cesar Pelli: Buildings and Projects 1965-1990 (pp. 9–12). New York: Rizzoli.

Gasparrini, C., & Terracciano, A. Eds. (2016). *Dross City. Metabolismo urbano, resilienza e progetto di riciclo dei drosscape.* Trento: List.

Gausa, M., Areti, M., & Vivaldi, J. (Eds.). (2019). *Black Ecologies.* Barcelona: Institute for Advanced Architecture of Catalonia and Actar Publishers.

Grulois, G., Tosi, M. C., & Crosas, C. Eds. (2018). *Designing Territorial Metabolism. Barcelona, Brussels, and Venice.* Berlin, Germany: Jovis.

HLPE (2022). *Critical, emerging and enduring issues for food security and nutrition. A note by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.* Rome.

Koolhaas, R. (1995). *Bigness, or the problem of Large.* In S,M,L,XL : small, medium, large, extra-large (pp. 494–517). New York: The Monacelli Press.

Lohrberg, F., Lička, L., Scazzosi, L., & Timpe, A. Eds. (2016). *Urban agriculture Europe*. Berlin, Germany: Jovis.

Marino, D., Antonelli, M., Fattibene, D., Mazzocchi, G., & Tarra, S. (2020). *Cibo, Città, Sostenibilità. Un tema strategico per l'Agenda 2030.* Roma, Italy: ASVIS.

Mininni, M. (2012). *Approssimazioni alla città. urbano, rurale, ecologia.* Roma, Italy: Donzelli.

Mougeot, L. J. A. (2005). *Agropolis. The social, political, and environmental dimensions of urban agriculture.* Ottawa, Canada: International Development Research Centre (IDRC).

Orsini, F., Pennisi, G., D'Alessandro, A., Kratochvilova, D., Steffan, G., Paoletti, M., Sabbatini, G., D'Ostuni, M., Trombadore, A., & Gianquinto, G. (2020). *Bridging interdisciplinary knowledge for sustainable urban landscapes: results from the international student competition UrbanFarm2019.* Acta Hortic. 1298, 97–106.

Panzini, F. (2021). *Coltivare la città. Storia sociale degli orti urbani nel XX secolo.* Roma: DeriveApprodi.

Parham, S. (2020). *Food and the garden city.* Territorio 2020, n. 95, pp. 53-62.

Rodotà, S. (2014). *Il diritto al cibo.* Milano: RCS MediaGroup S.p.A.

Sen, A. (1981). *Poverty and Famines. An Essay on Entitlement and Deprivation.* New York: Oxford University Press.

Sommariva, E. (2014). *Cr(eat)ing City. Strategie per la città resiliente.* Trento: LISt Lab.

Sonnino, R.; Tegoni, C.L.S., & De Cunto, A. (2019). *The challenge of food systemic food change: Insights from cities.* Cities, Vol. 85, pp. 110-116.

Steel, C. (2021). *Sitopia. Come il cibo può salvare il mondo.* Prato: Piano B.

Stringer, L.C., Fraser, E.D.G., Harris, D., Lyon, C., Pereira, L., Ward, C.F.M, & Simelton, E. (2020). *Adaptation and development pathways for different types of farmers. Environmental Science and Policy* 104 (2020) 174–189. https://doi.org/10.1016/j.envsci.2019.10.007

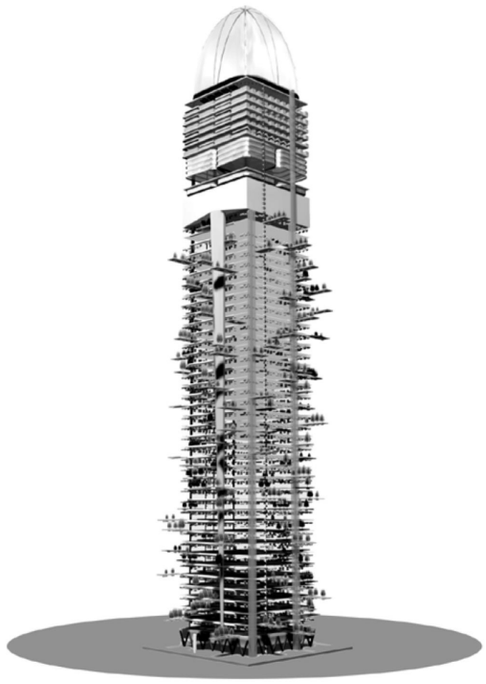
Viljoen A.; & Wiskerke H. Eds. (2012). *Sustainable food planning: evolving theory and practice.* Wageningen, Netherlands: Wageningen University Press.

Viljoen, A.; Schlesinger, J.; Bohn, K., & Drescher, A. (2015). *Agriculture in Urban Planning and Spatial Design. In Cities and Agriculture. Developing Resilient Urban Food System*; de H. Zeeuw, P. Drechsel, Eds. New York: Routledge; pp. 88-120.

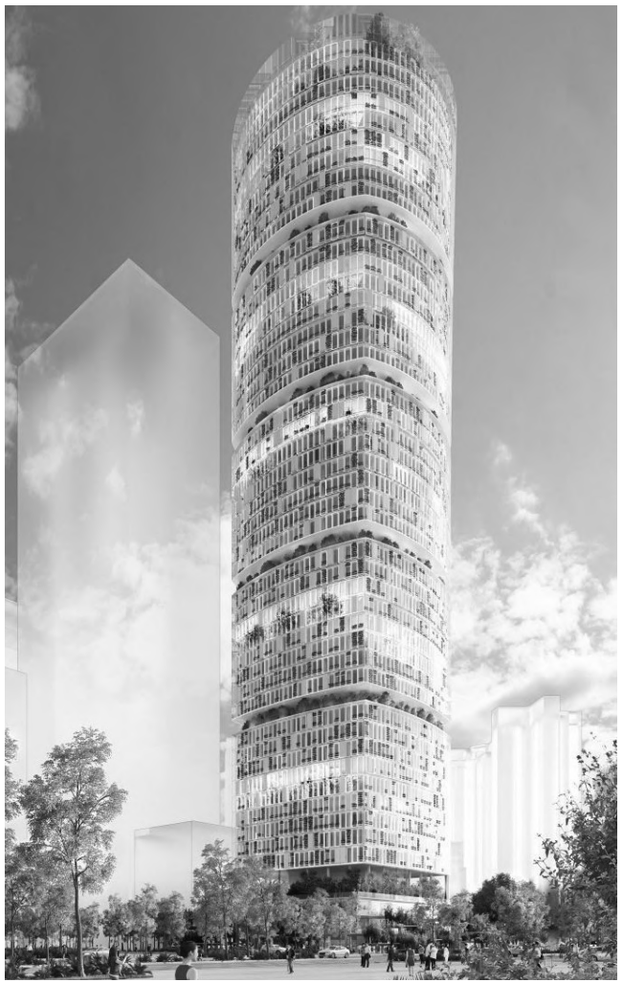
Willet, W. et alii (2019). *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems*, Lancet; 393: 447–92.

Wines, J. (2002). Vertiscapes: *The Skyscraper as Garden. In D. Gissen (Ed.), Big & green toward sustainable architecture in the 21st century* (pp. 78–87). New York: Princeton Architectural Press.

Gardens of Babylon. According to tradition they were built around 590 BC by King Nebuchadnezzar II.

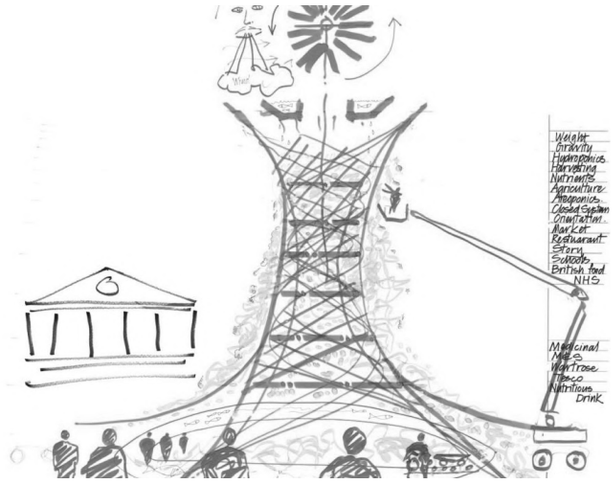


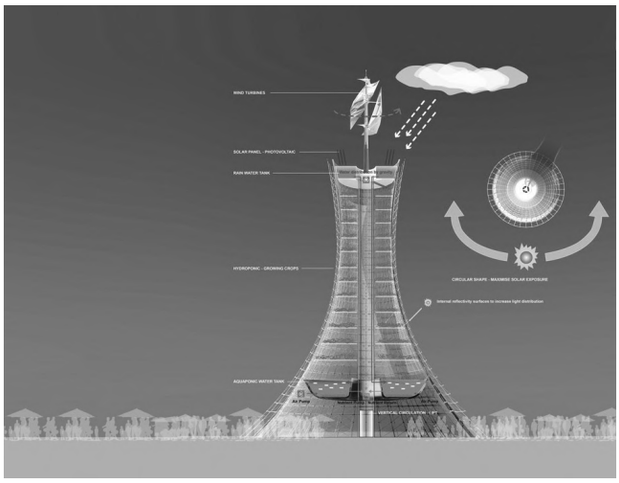
PigCity, vertical farm prototype, MVRDV, Holland, 2001



Farmscraper, vertical farm project, Carlo Ratti, Italo Rota, Arup, Farming System and Zero srl, Shenzen (China), 2016

Farmhouse, vertical farm prototype, Chris Precht, 2019





Skyfarm, vertical farm prototype, Richard Rogers (RSHP), 2015