Technical aspects of Urban Agriculture

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Module n°2

TITLE: Technical aspects of Urban agriculture

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Introduction

This module introduces and illustrates various urban agriculture typologies found in cities around the world. A distinction is done among traditional and innovative systems. Among the traditional systems, urban community supported agriculture is taken as an example and further described. Among the innovative systems, rooftop farms, urban aquaponics and vertical farms are described and detailed. Each system will be analyzed in terms of their characteristics, location, functions, technical aspects, development challenges and support needs.
The aim of the module is to answer the question: “What should I take into account, from a technical point of view, if I decide to start an urban agriculture activity?”

Duration: 12 hours – The duration of this module is eight hours of the lesson and four hours the practice of the exercises together with additional resources.

General information about the module

Learning outcomes

On successful completion of Learning Unit 2 participants should be able to…

Knowledge	Technical Skills	Soft Skills
• Know different typologies of UA initiatives business oriented • Know specific characteristics of CSA, rooftop agriculture, vertical farm and aquaponics • Learn about waste cycle and management within urban contexts • Understand the water cycle in an urban context and know how water can be recycled through UA initiatives	• Be able to identify the main steps to build a CSA • Be able to know which are the challenges related to a site where to establish a urban CSA • Be able to distinguish farming purposes of a rooftop farm • Be able to choose a site usable for a rooftop farm • Be able to size an aquaponic system	• Communicate about urban agriculture typologies, and related advantages and disadvantages; • Create an urban agriculture initiative, and relate it to a local context; • Know the most common problems when developing a urban agriculture initiatives, and develop problem-solving capacity

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Main content and resources

CHAPTER 1: Traditional Urban Agriculture (UA) systems

Agriculture can assume several forms in urban contexts, contributing to food security and urban environmental sustainability (**Taylor and Taylor Lovell, 2014**). Allotment gardens and community gardens are the eldest and most known forms of traditional urban agricultural systems. The first typology is mainly devoted to self-production, the second one to social engagement, and community building (**Orsini et al., 2020a**). On the other hand, community-supported urban agriculture (CSA) is mainly devoted to business and income generation. In this section, we decided to more deeply describe only urban CSA, as business-oriented UA typology. Nevertheless, in the section **Useful resources for the lesson,** at the end of the module, several external resources mainly related to allotment a community gardens development and management are reported.

1.1. Community-supported UA projects

The concept behind community-supported agriculture (CSA) is to find a way to sustain farming and farmers by ensuring that a farmer (or a group of farmers) has a market for his crops. The main idea is that a group of consumers get together with farmers in their vicinity. Together, they share the costs of the farming season, including land rent, seeds, tools and the farmers' salaries. And then, they share the products of the farm.
Different typologies of urban or peri-urban CSA may exist, each characterized by different features and management.

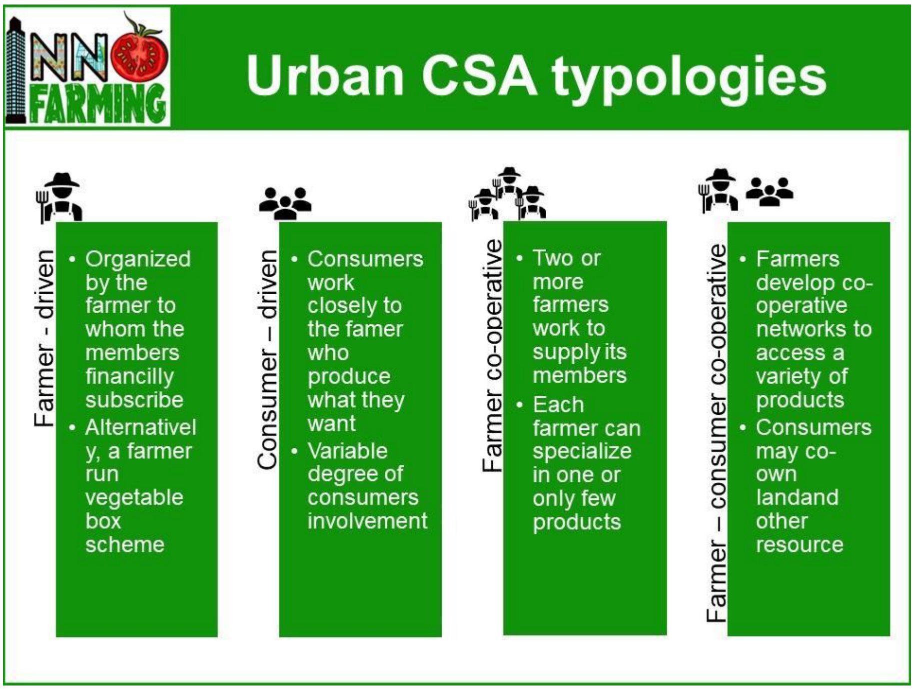

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Figure 1. Urban CSA typologies (redesigned from ***Pilley, 2001****).*

A well-designed CSA in an urban or peri-urban community can produce food, but can also serve as an economic engine providing employment to a farmer and other staff. Although the development and characteristics of each CSA are determined by location, circumstance and community, there are some fundamental steps that anyone wishing to undertake this activity must consider.
In the following sections we will give a more detailed description of the steps that we believe to be fundamental.

Figure 2. Eight steps to be considered for settlement of an urban CSA.

The people.
In order to develop an urban CSA, it is necessary to create two groups of people beyond the farmers.
The first one is composed by the consumers, members who bind the CSA and perpetrate the commitment during the time. Normally, they are guided by different reasons: to eat better, to become part of a local grown food movement, to help the environment, to support producers. This group of people may be found by using several strategies: publishing the urban CSA through the local paper, or preparing a brochure, giving presentation to civic or community organizations, talking with the local radio.
The second one is the core group which will be responsible for all CSA management activities beyond cultivation, e.g., member recruitment, communication, food distribution, finances, events organization. Farmers can be part of the core group, but if not, the core group is the connection between farmers and consumers. Usually, the core group is made up of CSA members belonging to the first group elected by a general assembly.

The site.
For an easier management of an urban CSA, at the beginning of the activity around 0.5 ha of land for 30 subscriptions are needed, but this can also depend on the crops grown (e.g., more land is needed to grow squash or potatoes or fruit trees). Furthermore, if a

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greenhouse is available, less land is needed because farmers will be able to have successive plantings during the year. But pay attention, because if you have to construct a greenhouse this will take away a lot of time and (in some cases) money and, in an urban context building permits may be required (**Schenk and Hotchkiss, 2014**).
Furthermore, when products harvesting will start, a place to store and distribute goods will be necessary. Depends on the available space, distribution time can be arranged in different ways. If the space is small, arrange staggered pickup times. If you do not have enough staff, organize the space in order to enable people to come in and independently select their products. Finally, if you have a small space but a several members of the staff available, organize the products boxes, so people can quickly pick up the boxes.

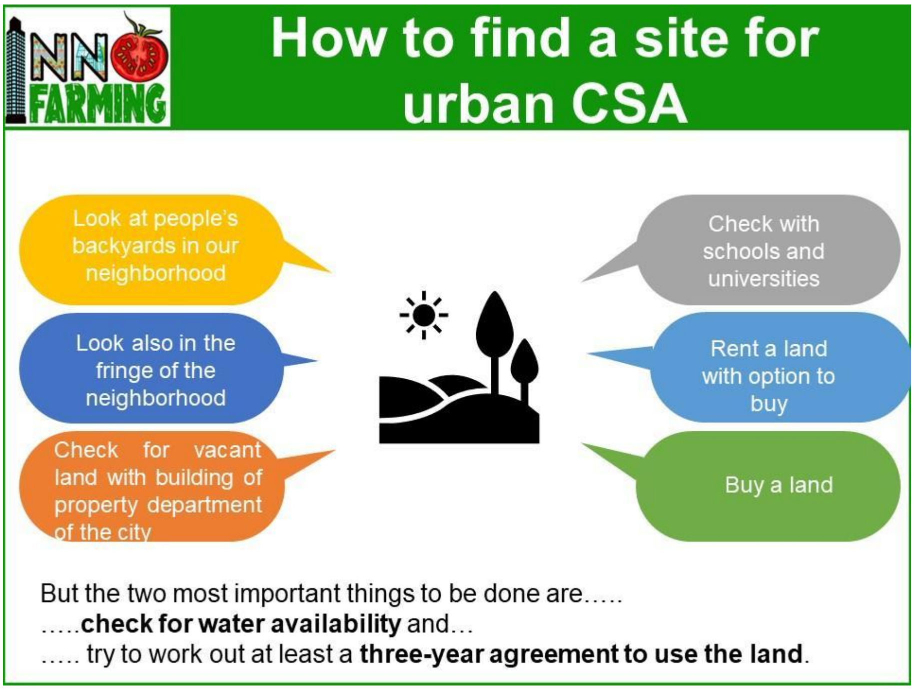

Figure 3. Steps to find a site for an urban CSA.

At the end, the right site will be found and the CSA activity can start. But, there are still some challenges related to the site that should be considered.

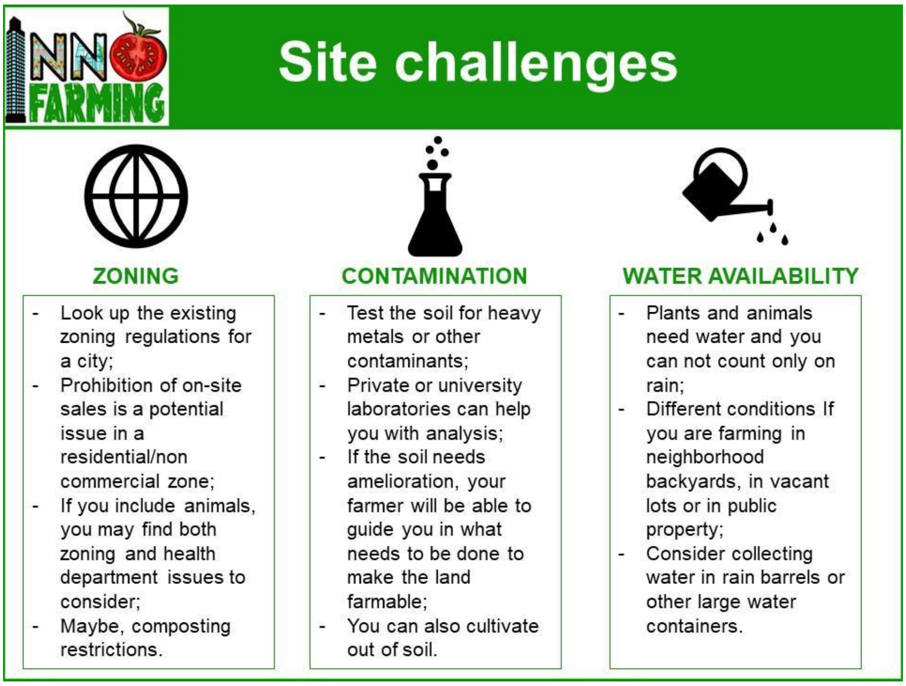

Figure 4. Other challenges related to the site for an urban CSA.

Setting the share size and the price.

In an urban CSA, each member receives a share of the total production, but it is fundamental try to quantify and price the share. The cost of a share should reflect the total production costs and considers also a salary for the farmer or grower. Usually, there are two ways to define the price of the share. The first one is to consider what a citizen normally spend on fresh product each week and provide the equivalent in CSA produce at market prices.

The second one, more sophisticated, is to prepare a budget estimate at the beginning of the season, and set a price on the base of the number of members and on the costs that should be faced during the season. The budget should consider expenses, including seeds, equipment, staff salaries (at least a farmer, and possibly assistant farmers and a farm manager or CSA coordinator), land costs, water costs, and other expenses (e.g., insurance, repairs and maintenances, taxes). Accordingly, at the end of the season shortfalls can be charged for or leftover funds returned or kept for the following season.
The economy of scale should also be considered: with the increase of the members number fixed costs are spread among more people. So, it makes sense to fix the share price considering to achieve a profitability considering the lowest members number that the CSA is likely to achieve. And then lower the price, if more people join the CSA.

In an urban CSA, the farming costs can be lowered involving the members in the work activities. In this case, it necessary to evaluate how many hours of work are needed for each share. Work can be directly related to farming, to compost activities, or activities related to running the business side of the CSA. In this case, setting the price for a work hour, knowing the number of hours of work “contained” in the share, people can pay instead of work.

Farming activities.

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Good organization and planning are fundamental for the success of the activities and the business. Quantifying the production to cover members needs depends on several factors:

- the number of urban CSA members, which helps to define the size of the share;
- the product of variety that the CSA wants to provide;
- importance of some products compared to others (e.g., tomatoes vs celery);
- crop failures.

Farming activities can be managed by using specific software available online, or creating a sort of crop map reporting what is sown, when it is transplanted, the duration of the cultivation cycle, when it is harvested, what is planted and what is harvested in each week of the season, with estimated yields for each crop.

Some literature suggests that twenty different types of vegetables and greens, with several varieties of some crops like tomatoes and lettuce, is a good starting point for a moderate-size CSA. At the beginning, choosing species that adapt well to the climate is an optimal and less risky choice. An interesting choice could be to establish some also some perennial crops (e.g., asparagus or berries) from the beginning.

Some crops can be grown directly from seeds, but for many other types of produce, you will plant seedlings started indoors or in cold frames, hoop houses, or some other protected space. Accordingly, it could be very helpful to find a space that you can use for this operation during the year.

In a CSA, food must be provided to people throughout the season (the duration depends mainly on weather conditions and the availability of a greenhouse), so planning is essential. To satisfy the members needs, some succession planting for several crops (e.g., lettuce and other greens, root vegetables, and beans) should be planned. In this case, making a planting schedule is very important.

Principal activities to start and manage the production in an urban CSA are:

- Soil preparation/Fertility; in this phase, soil analysis is needed to know physical and chemical characteristics of the cultivation substrate.
- Composting; rules of your city should be checked.
- Bed preparation; in an urban setting, if you are working on the site of an old industrial or public building, you might want to consider raised beds, because the soil onsite could be contaminated.
- Nursery; if you have a greenhouse, you can dedicate a place within it; other options for starting seeds in advance include simply constructed cold frames.
- Pest control; research what crops you should grow together to ward off certain insects (companion planting), and consider crop rotation and insect habitats when you make your planting plans.
- Irrigation; it should be automatized and based on soil characteristics, climate conditions and crops transpiration rate.
- Harvest.

<u>Distributing the produce.</u>

The easiest solution is to have a place dedicated to distribution (with a refrigeration room) where the cultivation occurs in order that products must not move. Two options are the most common:

- Boxed shares: advantages are that each member had the same share, and is time-saving for the members who just have to pick up their box and go. On the other side, members have no choices, and the “packaging” phase is time-consuming.

- Pack it yourself: members can choice your products and meet each other’s, no time is wasted by the workers for packaging the products; on the other side more space is needed and it takes longer for a member to come and pack up a share than to just pick up a box.

Urban CSA: an example from Bologna (Italy)

An interesting example of peri-urban CSA is Arvaia, located in Bologna, Italy. Arvaia was born in 2013, growing vegetables on 3 ha land. In 2015, Arvaia won the tender from the municipality of Bologna which assigned the entire area, of about 47 ha, for the management with a 25-year contract. Paying the rent to the Municipality, Arvaia started growing legumes and cereals in 2016 and at the beginning of 2017 it planted the first nucleus of the future orchard, which will also provide its members with fruit for about six months a year.

Figure 5. Pictures from Arvaia CSA.

Arvaia cultivates organically, practicing an agriculture without chemicals, sustainable for the land, labour intensive and not capital intensive and with a low impact on the land. It produces vegetables and fruit in season, without packaging and intermediate steps, providing them directly to members who contribute in different ways to produce them. It guarantees income for those who work and healthy food accessible to all through the solidarity mechanism of the community that supports agriculture.

Today, Arvaia has 476 members and grows 75 varieties, among vegetables, fruits and cereals. The price of the vegetables is around 750€ per year per “portion”. The portion is distributed for 50 weeks per year and is composed by round 7 kg of vegetables per week.

CHAPTER 2: Innovative UA systems

New technologies have been developed in order to address the low soil fertility and/or water availability, optimize the cultivation in limited spaces, and minimize the impact of the horticultural production to the environment and the human health. Such technologies have proven to be efficient in addressing these constraints, but need to be integrated into local farming and food systems. To have a chance to be adopted, they need to be associated with knowledge transfer and technical assistance. Some of them use natural substrates and various kinds of compost, others refer to simplified soilless systems. These highly intensive cropping systems find their application in urban and peri-urban areas where

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cultivation space is very scarce and its use very competitive. In the following sections, the most common innovative UA systems are described.

2.1. Rooftop farming

Rooftop farming is a form of innovative building-based UA, overcoming the problem of limited cultivable space in the cities by exploiting flat rooftops of different building typologies (e.g., offices, hospitals, schools, supermarkets, hotels, residential buildings etc.). Modern roof technologies were firstly developed in Germany, Switzerland and Scandinavia, as a way to increase environmental efficiency of buildings, decrease water run-off, increase urban biodiversity and counterbalance urban heat island effects (**Caputo et al., 2017**). Rooftop farming can be developed both in protected (*rooftop greenhouses*) and non-protected (*open-air rooftop farms/gardens*) conditions, applying advanced or household farming technologies, growing on soil (e.g., containers filled with soil, soil directly applied on rooftop surface) or using soil-less cultivation systems (e.g., hydroponics, aquaponics) (**Appolloni et al., 2020**).
The realization of a rooftop farm or garden should start from project definition, considering farming goals, site characteristics, garden typology, involved people and resources availability. The definition phase will be fundamental in order to have a clear idea on the challenges that may be encountered throughout project realization and operation.

Farming purposes.
The definition of goals or farming purposes is the first step to be taken when starting a rooftop farming project. Basing on cultivation goal, rooftop farming experiences can be classified in five different categories: commercial, social, image, innovation or urban living quality (**Thomaier et al., 2015**).

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Rooftop farming purposes

Image	Cultivation with aesthetic and marketing aims, especially applied on hotels, restaurants and cafeterias processing the production
Urban Living Quality	Projects for amelioration of living quality of urban residents and employees, offering a green space where to produce their own food and recreate. It is often applied on residential buildings or offices
Commercial	Food production with for profit purpose, often performed by start-ups or agricultural enterprises
Social and Educational	Projects aiming at teaching social and ecological values, often applied on schools or non-profit institutions
Innovation	Cultivation for research and innovation purposes, often applied on universities or research centers

Figure 6. List of rooftop farming purposes.

The project purpose will inevitably affect the selection of techniques and technologies and the approach to design the rooftop farm. **Sanyè-Mengual et al.** (**2015**), in a study addressing an experimental project in the rooftop of a social housing in Bologna (Italy), affirmed that, looking at environmental impact, conventional cultivation on soil in containers is more advantageous as compared that conventional hydroponics in winter months. Contrarily, if the purpose is the productivity maximization, hydroponic systems may enable a higher yield as compared to conventional agriculture techniques with the same cultivation area (**Grewal and Grewal, 2012**).

<u>Project site.</u>
Due to the peculiar location on a rooftop, site characteristics are a fundamental aspect to be considered for the development of an effective rooftop farming project. Site choice may influence duration (temporary or permanent), accessibility of cultivation resources, production scale and user's safety. Therefore, rooftop farmers should consider several factors before setting up their project, eventually adapting the location in order to maintain the best conditions while performing the gardening activity (**Germain et al., 2008**).
One of the more important influencing factors for rooftop farming diffusion is the availability of buildings, which refers to the need for the building to withstand higher loads due to the weight of soil and other equipment. Considering structural loads, a common classification of green roof considers three main categories according to the substrate depths, as reported in **Table 1**.

*Table 1. Main substrate features of extensive, semi-extensive and intensive green roofs (**Caputo et al., 2017**).*

	Extensive	Semi-extensive	Intensive
Depth of substrate	60-200 mm	120-250 mm	150-400 mm
Structural load	60-150 kg m^{-2}	120-200 kg m^{-2}	180-500 kg m^{-2}
Cost	low	periodic	high

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Loads associated with the minimum depth for rooftop farming may not constitute a major problem if the farm is integrated in a new building and loads are considered from the onset of the design process. In existing buildings, these loads may not be compatible with the carrying capacity of the roof.
This is also true for rooftop greenhouses, which may not necessarily have a great weight in terms of structure and external cladding, due to the construction consisting of aluminum elements with an envelope of polycarbonate panels. However, depending on the equipment used for method of cultivation, the total load may critically increase. As reported by **Caputo et al.** (**2017**), another key factor when planning a rooftop greenhouse is the load of winds, which becomes bigger with the height of the building, thus requiring particular attention to the robustness of the connection of the greenhouse to the existing building structure and of the greenhouse itself. Finally, great consideration must be given to water tanks representing a major load on parts of the roof.

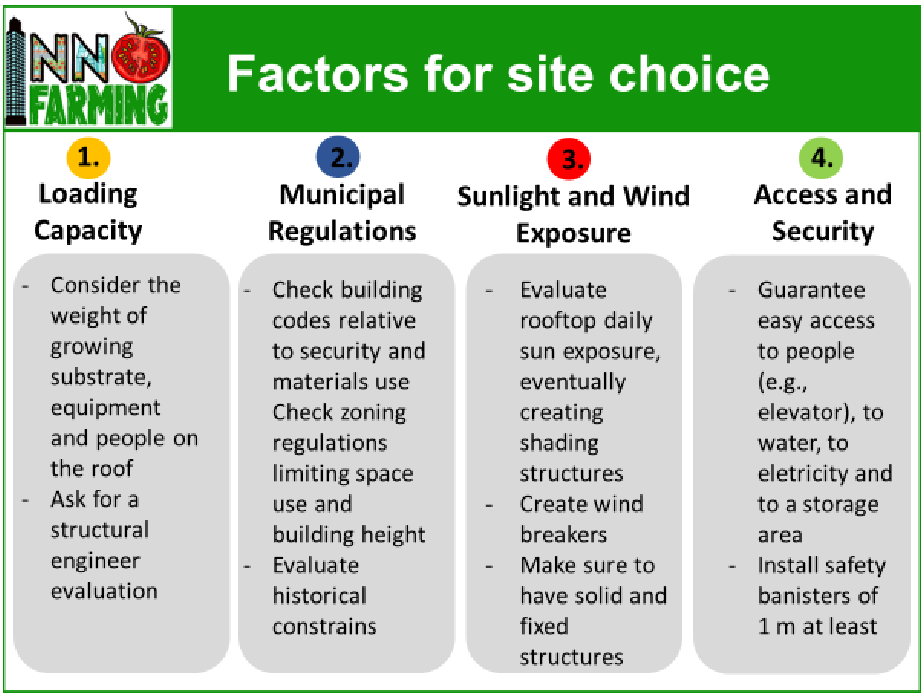

Figure 7. Factors that should be considered for choosing the site for a rooftop farm.

If not independent, access to the rooftop may be a problem. A formalized agreement with building inhabitants is necessary for vertical circulation. Alternatively, external stairs can be built and added to the existing buildings.
Safety is another crucial point because in existing buildings, rooftop is often not designed to host people. Adequate railings, if not already present, must be built.

Design and realization.
Once the project has been defined and the site has been chosen, the realization of the rooftop farm/garden can start. A rooftop farmer can decide if ask for help designing the project, hiring an expert professional such a landscape architect. However, project realization can also be performed independently. In this case, 3 fundamental steps should be considered in order to avoid mistakes.

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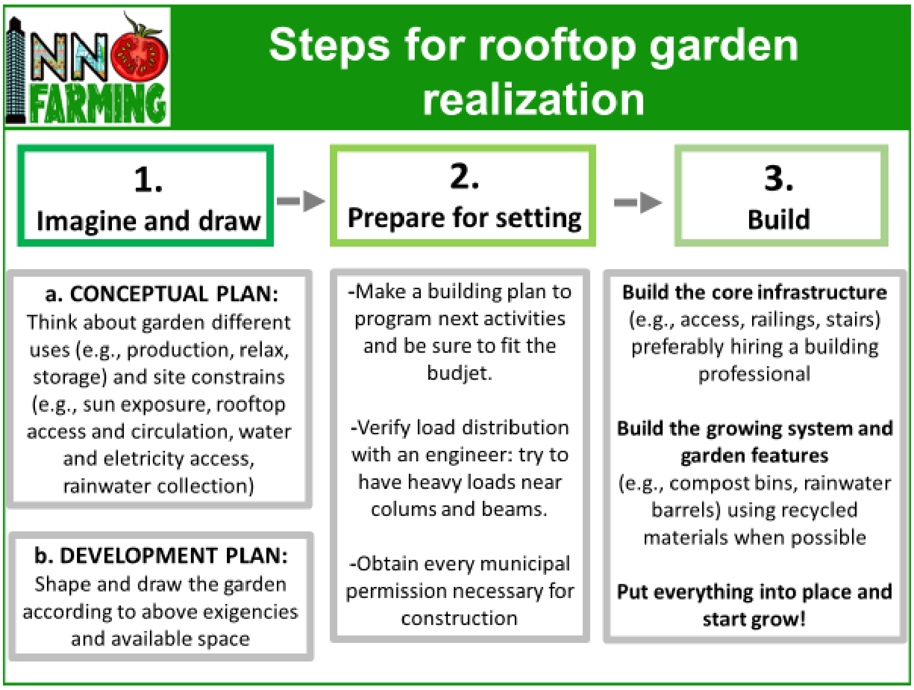

Figure 8. Steps for the realization of the rooftop farm.

<u>Soil Based and Simplified Hydroponics Rooftop Gardens.</u>

Commonly used systems for rooftop production are soil-based, water based or substrate systems. The last two systems are commonly known as hydroponic systems or soilless cultures. The advantages of hydroponic rooftop farming are (**Rodríguez-Delfín et al., 2017**):

- Locations unsuitable for traditional agriculture are exploited;
- Yields obtained with hydroponic systems are generally higher as compared to traditional soil-based solution (due to faster and vigorous plant growth, as well as increased number of harvests per year);
- Low water and fertilizers consumptions;
- No fertilizers leakage;
- Hydroponic rooftop farming can also be used for social purposes to improve the incomes of disadvantaged populations to generate self-employment in their own homes.

Concerning soil-based cultivation systems, they usually integrate cultivation beds (constituted by soil from agricultural fields, mixed with organic matter and other substrates) and walking paths. Soil depth will depend on building structural limits, soil water holding capacity and crop requirements. When saturated with water, a cubic meter of soil may weigh up to 1.6 tons (**Fairholm, 1999**), exceeding the load-bearing capacity of the rooftop. Accordingly, lightweight substrates or growing media may be used alternatively to the soil. Organic growing media and others, such as perlite and pumice are usually used in containers.

Concerning soilless cultures, the most commonly adopted are the nutrient film technique (NFT), or the float hydroponics.

Further details on growing media and soilless cultures for rooftop agriculture can be find in **Rodríguez-Delfín et al. (2017)**, **Gruda et al.** (**2013**), and **Savvas et al.** (**2013**).

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Technology for Rooftop greenhouse.

Usually, farmers decided to use a greenhouse in order to protect crops against hostile conditions, such as unfavorable temperature, rain, wind, disease and pests.

The key factor of a greenhouse is the light transmission, which can depend on greenhouse orientation, roof slope, covering material and structural parts.

Concerning greenhouse orientation, east to west orientation (E-W) is preferable over north to south orientation (N-S), according to different studies conducted on conventional greenhouses. Considering roof slope, a 30° roof slope is a good compromise between light transmission and construction costs (**Montero et al., 2017**).

The major loss of light transmission in a greenhouse is due to structural parts, which in rooftop greenhouse are more abundant, due to local building codes which are more demanding as compared to rural ones in terms of coefficients of security against wind load and snow load, load combination, displacement allowances and so on.

Concerning covering materials, **Table 2** contains desired optical properties of greenhouse ones.

*Table 2. Main substrate features of extensive, semi-extensive and intensive green roofs (**Montero et al., 2017**).*

Property	Optimal behavior
Absorbance	Minimum absorbance to solar radiation
Color	Should not act as light filter
Photosensitivity	UV resistance to avoid degradation
Reflectivity	Minimum reflection to PAR, maximum reflection of IR
Transmittance	Maximum transmittance to PAR, minimum transmittance to FIR
Solar diffusion	Higher as possible, without limiting PAR transmission

Rooftop greenhouses have the same purposes and requirements as a conventional on-soil greenhouse, but they also have some specific characteristics, mainly related to structural parts to comply with building construction codes, which are stricter than agricultural codes. For example, the ICTA-ICP building in Bellaterra (Spain) had to adapt common greenhouse structures: steel structure was oversized to ensure wind resistance, and polycarbonate was used as covering material, because light density polyethylene (LDPE) was forbidden. Indeed, materials for rooftop greenhouse should respect fire safety laws and should be more resistant.

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Figure 9. Rooftop greenhouse at ICTA-ICP building in Bellaterra (Spain).

Also cost, maintenance and weight are considered limiting factors in the selection of the materials. Polycarbonate and polymethyl methacrylate (PMM) can be used as single layer (higher light transmission) or double layer panels (high heat energy saving).
General information about greenhouses can be found in [Good Agricultural Practices for greenhouse vegetable crops].

Sustainable management.

Once the rooftop garden is ready to grow, the farmer should start thinking about plants selection and management. A sustainable management is an important aspect to consider in case of rooftop farming, in order to avoid health risks for people living nearby and resources competition for other urban uses (**Orsini et al., 2017**).
Concerning health risks, the use of pesticides, herbicides and chemical fertilizers should be avoided on a roof, using alternative resources not harmful for human health. Compost may be used as a fertilizer, while the association of synergic plants or natural pesticides could help to naturally control insects and diseases development. Furthermore, since compost is a fertilizer obtained from the decomposition of organic waste, its application can help closing the food cycle with positive consequences on environment, as well as to reduce costs for plants nutrition. An optimal growing substrate is represented by a mix of soil, 50-30% of compost for nutrition and 5-10% of perlite for drainage.
Water is the resource for which competition is most created in an urban context. The use of municipal water for farming purposes may determine an excessive pressure due to contemporary use by urban dwellers and industrial activities. For this reason, a rooftop

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farm or garden should consider the integration of a system for rainwater collection. This watering source is the pest option for plants irrigation, having a naturally warm temperature that will not shock the plants and being free from chlorine that may constrain plants growth. However, rainwater should be collected and storage properly, avoiding mosquitos' entrance and algae formation by using nets and dark barrels.

Figure 10. Steps for the realization of a rainwater collector.

<u>Brooklyn Grange: the most famous rooftop farm in the hearth of New York City.</u>

[Brooklyn Grange]() is a commercial urban farm. To date, they farm three rooftops in New York City. The one-acre (43000 m^2) Long Island City Farm was built in 2010, and is made up of roughly 540 tons of soil across 43000 m^2 of cultivated growing beds. The Navy Yard farm, built in 2012, comprises 1360 tons of soil atop a 65000 m^2 building. The Sunset Park farm, completed in 2019, is 140000 m^2 in total, including a 4800 m^2 greenhouse. As a global, the total rooftop acreage including greenhouses, patios, and walkways, is 22 ha.

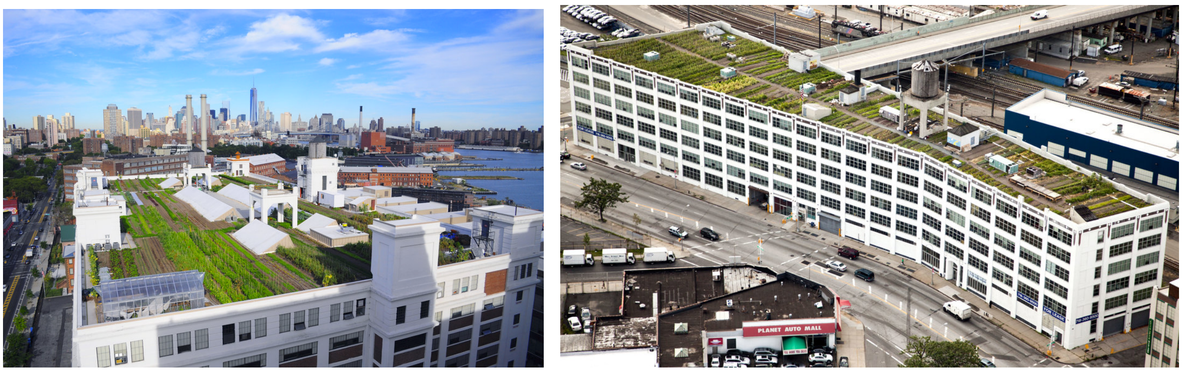

Figure 11. Brooklyn Grange rooftop farms (Source of the photo: https://www.brooklyngrangefarm.com/about-brooklyn-grange-1)

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Brooklyn Grange is the largest rooftop farms all over the world and produces 45 tons of organically-cultivated vegetables per year. The farm sells the produce directly to the community at five weekly markets as well as several local restaurants and retail stores. During summer, they also have a thriving CSA program through which distributes shares.

For technical information related to rooftop agriculture:
download Rooftop Agriculture or read Rooftop Urban Agriculture

2.2. Urban aquaponics

Aquaponics is a bio-integrated food production system, resulting from the combination between the fish farming activity (aquaculture) and the soilless plant production system (hydroponics) (**Palm et al., 2018**).

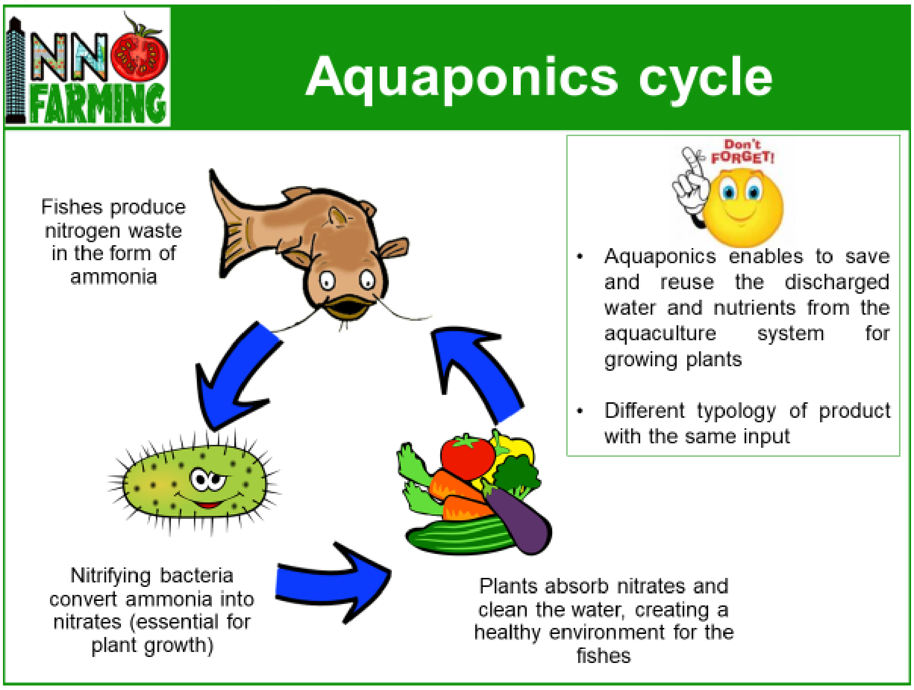

Figure 12. Closing the water and nutrients cycle with aquaponics.

<u>The system.</u>

An aquaponic system is composed by:

- **Fish tank**: the tanks for raising and feeding fishes; the **sizing** depends on the targeted fish density and biomass; a **round shape** with flat bottoms is recommended for water circulation and solid wastes movements; **plastic** (e.g., low-density polyethylene) **or fiberglass material** is recommended because of their durability and long life span; **white** tanks are advised for easier viewing of the fish in order to easily check behavior and the amount of waste settled at the bottom of the tank, and also to keep the water cool; **tank should be covered** to prevent accidental losses.
- **Mechanical filter**: a unit for catching uneaten food and detached biofilms, and for settling out fine particulates; in systems with a lower stocking density (<10 kg/m^3) devices based on **sedimentation for particle removal** (for particle size ≥ 100 μm), while systems with a higher stocking density (>10 kg/m^3) may need **rotational drum filters** (for particle size ≥ 30 μm) and **foam fractionators** (for particle size ≤ 30 μm).

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- **Biofilter**: a place where the nitrifying bacteria can grow and convert ammonia into nitrates; if plants are grown in a media growing bed (so a substrate is used) and the fish stocking density is low, a biofilter is not needed; in all the other possible conditions, the most used biofilter is the **moving bed biofilter reactor** (MBBR), composed by small plastic structures with high specific surface, kept in constant movement and constantly aerated (e.g., Bioballs®).
- **Hydroponics subsystem**: the portion of the system where plants are grown; usually, it consists of bed filled with several substrates, or hydroponic systems (e.g., nutrient film technique or deep water culture).
- **Sump**: the lowest point in the system where the water flows to and from which it is pumped back to the rearing tanks.

<u>Starting to design an aquaponics system.</u>
The design of a new aquaponic system should be based on your goals and requirements and should consider:
- the purpose of the system (e.g., business, self-production, educational, aesthetic);
- the site and available space (e.g., for a commercial system at least 1000 m^2 are needed);
- the location (e.g., if the system is located indoor lighting will be necessary, if the system is placed outdoor heating is necessary, but probably construction costs will be lower);
- the management of the system (e.g., automation is expensive, but manual labor is time consuming);

The design and construction of an aquaponic system follows a series of sequential steps: feasibility study and site selection, basic design, detailed design, construction site preparation, and construction.

<u>Feasibility study: location and infrastructure.</u>
The basic needs required to the site to host an aquaponic systems are:
- **site stability**; due to the water weight, the loading capacity of the ground should be checked;
- **climatic conditions control**; during periods of low temperature and short daylight, stop the production is an option, in order to start again in spring; the other possibility is to heat the water and air and provide artificial lighting (but, pay attention to the costs). On the other hand, extremely high temperatures have to be avoided during summer. It is possible to install shading nets, or in case of greenhouse production, paint the outside of the greenhouse with white paint;
- **utilities**; electric outlets for the pumps an oxygen (or air) generators and water source for water changes or for cleaning filters are needed. It is important also to consider where any effluents should go.
- **accessibility**; the location should be accessible to move materials, harvested plants, fishes and in case of emergency; on the other side, it should be protected by unauthorized people because of the risk of infections and disease.
- **working spaces**; in this phase of feasibility study, places for storage fish food, cleaning material and tools, monitoring equipment and work clothes should be considered.

<u>The balancing of the aquaponic system.</u>

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An aquaponic system is the result of an equilibrium between plants, fish and bacteria (**Sallenave, 2016**). Fishes should supply adequate nutrients for the plants and the plants should filter the water for the fished. The biofilter needs to be large enough to process all of the fish wastes, and enough water volume is needed to circulate this system.

First of all, it is fundamental to say that fishes, plants and bacteria have different optimal ranges of physio-chemical parameters of the water:

- Warm water fish: 22-32°C, pH = 6-8.5, 4-6 mg L^{-1} DO (dissolved oxygen)
- Cold water fish: 10-18°C, pH = 6-8.5, 6-8 mg L^{-1} DO
- Plants: 16-30°C, pH = 5.5-6.5, ≥3 mg L^{-1} DO
- Bacteria: 14-34°C, pH = 6-8.5, 4-8 mg L^{-1} DO

Usually, the use of the **feed rate ratio** is the most effective way to balance an aquaponic systems. The ratio evaluates how much fish feed should be added each day to the system, considering the **area available for plant growth**. It changes as a function of the type of plants being grown (40-50 g m^2 day^{-1} or 50-80 g m^2 day^{-1}, respectively per leafy of fruity vegetables), and the type of feed used.
The first step is to calculate how many plants are desired (considering that in general **planting density** is 20-25 plants m^{-2} for leafy vegetables and 4-8 plants m^{-2} for fruity vegetables), and consequently the needed amount of growing area.
Once the growing area is known it is possible to calculate the amount of fish feed that can be added to the system every day and, consequently, the biomass of fish needed to eat this fish feed, considering that different-sized fish have different feed requirements and regimes (meaning that many small fish eat as much as a few large fish), but on average, the fish will consume 1–2% of their body weight per day during the grow-out stage. To finalize the system, it should be added that the recommended maximum fish stocking density is 20 kg of fish for 1000 L of water (fish tank).
Finally, also the volume of the biofilter should be calculated considering the amount of feed entering the system daily and considering a minimum volume of 0.5 L per gram of daily feed.
An example of calculations for balance the aquaponic system is reported in **Figure 13**.

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Example of calculations to balance the system

- A 100 m^2 system is available for growing leafy vegetables, resulting in 2'500 plants in the system.
- Considering the feed rate ratio for leafy vegetables:

$$100\ m^2 * \frac{50\ grams\ feed\ /\ day}{1\ m^2} = 5000\ grams\ feed\ /day$$

- The fish (biomass) in a system eats 1–2% of their body weight per day, therefore:

$$5000\ grams\ feed\ /\ day * \frac{100\ grams\ fish}{1-2\ grams\ feed\ /\ day} = 250 - 500\ kg\ fish\ biomass$$

- Considering a fish stocking density of 20 kg m^{-2}, 13-25 fish tanks of 1'000 L will be needed to balance the system (or 4-8 tanks of 3'000 L).
- Finally, considering that the daily amount of feed entering the system is 5'000 grams, a biofilter of 2'500 L should be added to the system.

Figure 13. Example of calculations to balance an aquaponic system based on the feed rate ratio.

<u>Management practices.</u>

In order to proper manage the aquaponic system, there are some activities that should be performed on a daily, weekly or monthly base (**Somerville et al., 2014**; **Junge et al., 2020**).

Daily activities.

- Feed the fish (1-2 times a day if possible), check how much feed has been eaten and in case it is necessary, adjust feeding rates.
- Anytime you fish the feed, check the behavior and appearance of the fish, and remove dead fish, taking care to write down any important comment.
- Check that water is flowing.
- Check the water level, and add additional water to compensate for evaporation, as necessary.
- Check water temperature.
- Check that the water and air pumps are working well, and clean their inlets from obstructions.
- Check the fish tank, where no sludge should be present.
- Check for leaks.
- Check the aeration in the biofilter and cover the biofilter to shield it from light (prevention of algae growth)
- Check the plants for pests and manage pests, as necessary. Remove leaves with signs of disease or pest infestation.

Weekly activities.

- Perform water quality tests for temperature pH, ammonia, nitrite and nitrate before feeding the fish. If the levels exceed threshold values, take appropriate action:

  If NH^4+ or NO_2 are too high, stop/reduce feeding

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If O_2 is too low, or NH^3 or temperature too high, increase aeration and reduce temperature using a plate heat exchanger

- Adjust the pH, as necessary.
- Check the plants looking for deficiencies. Add organic fertilizer, as necessary.
- Clear fish waste from the bottom of fish tanks and in the biofilter.
- Remove sludge from the sludge trap. There should be no sludge in the pipes
- Plant and harvest the vegetables, as required.
- Harvest fish, if required.
- Check that plant roots are not obstructing any pipes or water flow.

Monthly activities.

- Stock new fish in the tanks, if required.
- Clean out the biofilter, clarifier and all the filters.
- Clean the bottom of the fish tank using fish nets.
- Weigh a sample of fish, adjust the amount of feed according to the feeding rate suitable for the size of the fish and check thoroughly for any disease.

Plants and fishes suitable for aquaponics.

Fishes and plants grown in an aquaponic system should have similar needs as far as temperature and pH.

Fishes usually raised in aquaponics are:

- tilapia;
- carp;
- catfish;
- blue gill/brim;
- sunfish;
- crappie;
- koi;
- fancy goldfish;
- pacu;
- various ornamental fish such as angelfish, guppies, tetras, swordfish, mollies.

Plants that can be easily grown in an aquaponics unit are:

- leafy greens (e.g., lettuce, pak choi, kale, swiss chard, arugula);
- herbs (e.g., basil, mint, chives);
- fruity vegetables (e.g., tomato, pepper, cucumber).

ECF FARM Berlin: an aquaponic farm in Berlin (Germany).

Located in Berlin Schöneberg, ECF Farm Berlin is one of the world's most modern urban aquaponics facilities. The farm products are Perch fish and potted basil plants. The total farm surface is 1800 m^2, with a greenhouse area of 1000 m^2. The farm workers are 8 people in total: 2 fish growers, 3 greenhouse growers, and 3 planning and management staff. Usually, the fish is marketed under vacuum and kept at 2°C, and sold as frozen fish through a middle-company (that has certified marketing channels for fresh fish products). Sometimes, they sell as fresh fish, with much greater logistic effort. Fish price is around 7

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€ kg^{-1} at ECF, and then the middle company sells the product at 9 € kg^{-1}. Potted plants are producing in greenhouse by using a hydroponic system (called ebb-and-flow systems), where 2000-4000 L of fish water are recirculated from fish tanks to the greenhouse each day. Usually, 400000 pots are produced per year, which are sell in plastic free packaging. Supermarket chain (Rewe) pays 1-1.5 € $plant^{-1}$ to the farm, and sells at 2.5 € to the public

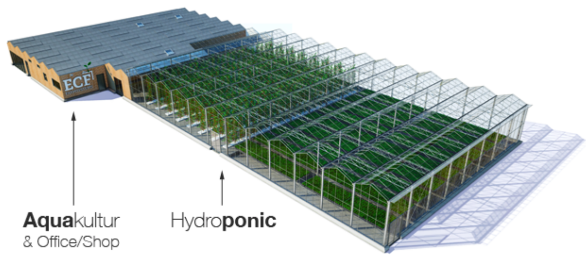

Figure 14. ECF FARM Berlin buildings (source: Pinterest) and greenhouse (source: https://greencardgardener.com/2017/03/27/urban-farming-berlin-style/).

For technical information related to urban aquaponics:
download Small-scale aquaponic food production or read Aquaponics Food Production Systems

2.3. Vertical farming

A vertical farming system is a system where crops are grown in controlled indoor environments with proper temperature, light, and nutrients.

These farms are normally located in urban communities or close to them. Abandoned or new building constructions can be proper sites to develop this farming system. Another option that is gaining attention to place a vertical farm are shipping-containers, which can be refurbished into self-contained vertical farms for plant growth.

A **vertical farm** consists of six principal structural elements (**Kozai and Niu, 2016**):

- a well-insulated and nearly airtight warehouse-like structure covered with opaque walls;

- a multitier system (mostly 4–16 tiers or layers; about 40 cm vertically between tiers) equipped with lighting devices over the culture beds;
- air conditioners (also known as heat pumps), principally used for cooling and dehumidification to eliminate heat generated by lamps and water vapor transpired by plants in the culture room, and fans for circulating air to enhance photosynthesis and transpiration and to achieve a uniform spatial air distribution;
- a CO_2 delivery unit to maintain CO_2 concentration in the room at around 1000 ppm during the photoperiod for enhancing plant photosynthesis;
- a nutrient solution delivery unit;
- an environmental control unit including electrical conductivity (EC) and pH controllers for the nutrient solution

Advantages of vertical farms as compared to more traditional growing systems are:
- constant and high yield are possible throughout the year;
- no pesticide use, elevate land, water and nutrient use efficiency;
- independent from solar radiation or soil fertility;
- easier logistic chain;
- wider choice of varieties and increased freshness;
- lower food waste, more uniform quality, absence of dirt, high harvest index.

On the other hand, it should also be noted that greenhouses are also adaptable to harsh climatic conditions, investment costs for vertical farms are 4x to 10x higher than a high-tech greenhouse and artificial light requires electricity while a greenhouse benefit from solar radiation. Accordingly, electricity costs account for the 30% of the total production costs in a vertical farm, and among these, 50% are related to artificial lighting.

However, in order to have greater chances of success, several important factors should be considered when designing a vertical farm. In these terms, the vertical farmer should look for produce the best product. This is because growing indoor allows to optimize and control many parameters of the plant growing environment, achieving in this way a proper crop development.
But first of all, the first decision that growers will need to make is what to grow. The second is how to grow it. Therefore, special attention was given to the factors which could be considered the crucial ones when starting a vertical farm. Information regarding these main considerations is presented in sequence.

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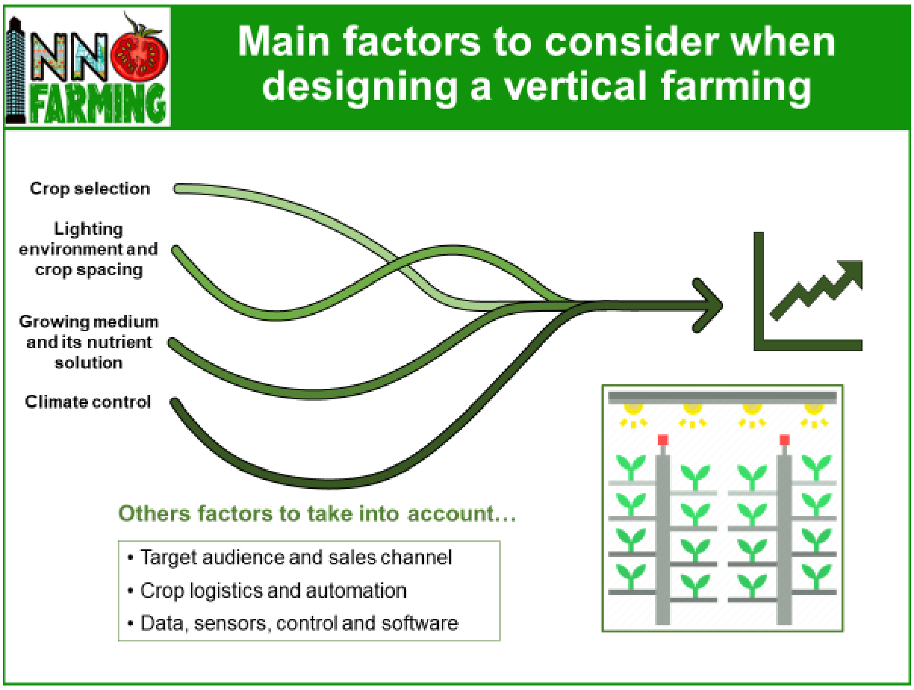

Figure 15. Main factors to consider when planning to build a vertical farm.

Crop selection.

Nowadays, leafy greens and herbs are the most common crops of the vertical farming industry. These plants are a good choice if the purpose is to be economically efficient. Since leafy greens and herbs are characterized by a fast growing, several harvests can be performed per year and less costs are needed, especially for energy, due to the low lighting requirements. For instance, fast growing crops such as lettuce, cabbage, mint, cilantro, parsley, basil, etc., can usually take up to six weeks to produce. Recent studies are addressing the possibility to cultivate medicinal plants in vertical farms. The fully controlled environment of a vertical farm enabled to obtain final products with the same morphological and nutraceutical characteristics all over the year. This aspect, for this kind of plants commonly used for industrial transformation, is of crucial importance. Also, microgreens and sprout can be adapted to the cultivation in a vertical far, but also cash crops with high values (e.g., *Cannabis*).

Lighting environment and crop spacing.

One of the essential components of success in vertical farming is to provide a proper light according to the crop's requirements. Each tier in which the plants grow vertically should have an artificial lighting source able to provide a quantity of light during a certain period of time along the day in order to ensure the sufficient growth of the plants. The purpose of this lighting is to simulate the daylight according to the need of the growing crop. If we consider the lighting sources of the actual market, the development of light emitting diodes (LEDs) have become as the most interested solution for growing plants and vegetables, characterized by a low energy consumption. Moreover, LED light can be configured to provide only those light frequencies according to the requirements of each plant and they do not release excessive heat that could cause plant burning. Several researches were already performed about light management in vertical farms facilities (**Pennisi et al., 2019a**; **Pennisi et al., 2019b**; **Pennisi et al., 2020a**; **Pennisi et al., 2020b**).

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Furthermore, a proper spacing strategy of the plants can be made to increase the production in function of the quantity of light provided. Plant overlapping or conversely, too much space between plants, can lead to a loss in productivity and not an efficient use of the light. A proper distribution of the plants in a way that each plant gets the optimal amount of light will avoid to waste light by illuminating areas without plants.

Growing system and its nutrition solution.

Hydroponics is usually used in vertical farms, which is based on the concept of growing plants in a nutrient-rich solution. As already said in the rooftop farming section, this practice works in a way in which the plant roots are suspended in a nutrient-rich water basin with recirculated water (e.g., in floating systems or nutrient fil technique) or, otherwise, by roots supported in a non-soil medium (e.g., peat moss, coconut husks and rockwool) to which is provided the nutrient solution.

Another interesting hydroponic system for vertical farms is aeroponics, a method in which plant's roots are fed and watered mid-air, by spraying the nutrient solution. The nutrient solution not absorbed by roots is drained back into the reservoir and recycled. Aeroponic is considered the most efficient technology in terms of water saving capacity. A drawback to current aeroponic systems is maintaining root health in the event of pump malfunction or loss of power. Without the spray of nutrient enriched water, root systems will not remain healthy for long. They will rapidly dry up and die.

Vertical farm requires to give special attention and knowledge to the nutrient solution provided to plants. Depending on the type of crop and its growing phase, the nutrient solution composition can be altered with the purpose of favoring an optimal plant development along its growing cycle.

Control all the climate parameters.

An important aspect that new vertical farm growers should pay attention is to create the best climate conditions for its crop. Parameters such us having the temperature under control or keep a proper humidity should be in combination with a good ventilation and adequate management of the air system. Cooling, dehumidification and heating systems have to be considered for a proper management of the climate. The not suitable control of these environmental parameters that surround the crop can lead to a decrease in the final yield with consequences driving to higher costs.

On the other hand, vertical farmers should consider all the possible factors for a proper planning. It should be developed a marketing strategy in order to get known around the community. An adequate promotion of the final products is essential to reach the customers. Moreover, growers can take advantage of the technological era that we are experiencing by monitoring and automatizing its production thanks to the use of sensors, computer software's and other control devices.

In this context, vertical farming can sound like a promising farm of the future, however, before starting a project like this an overlook on the pros and cons of this farming should be considered. Consequently, the following figure presents the great opportunities of this industry, but also some of the challenges that need to deal with.

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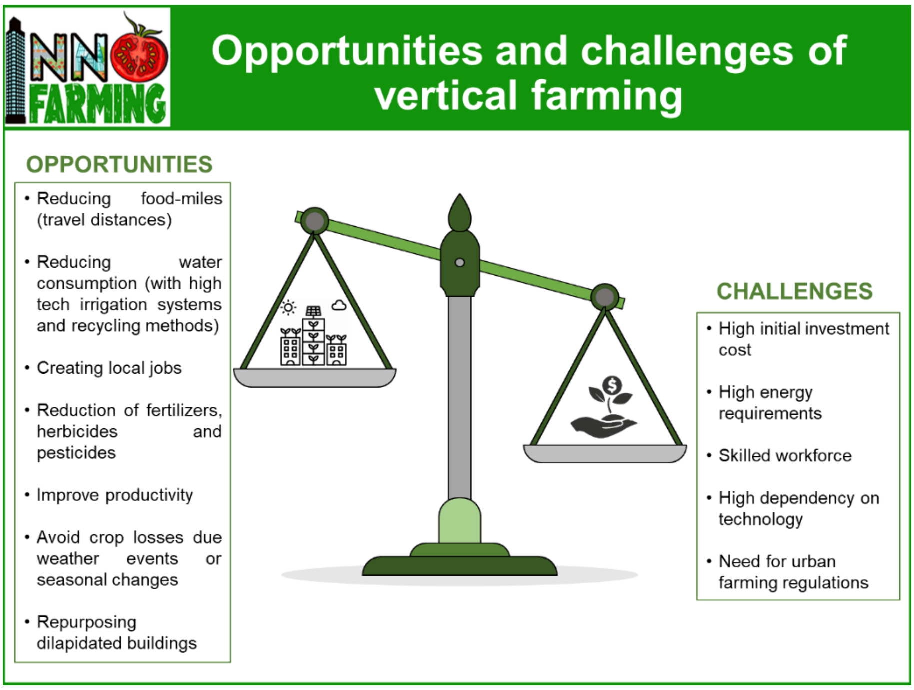

Figure 16. Opportunities and challenges of vertical farming.

The main barrier for implementing a vertical farm is the large investment needed. Therefore, a funding and financing strategy should be explored. Particularly, if it is wanted to set-up the vertical farm for profit, a study on its economic viability and the economics of the species that will be grown need to be considered. The decision on starting to produce can be by establishing a small scale or large scale vertical farm depending on farmer goals and requirements. In addition, the fact that this farming is a recently new industry means that regulations and policies are still developing. In this context, new farmers should explore the current law and policy in order to avoid confusion and problems.

Nevertheless, vertical farmers and its industry are trying to find solutions in renewable sources, such as solar and wind, as a way to generate electricity and reduce the energy costs in the structure. Rainwater tanks could also be useful to safe water, even if indoor farming uses much less water than conventional farming practices. Vertical farm has the potential to play an important role in the sustainability of food in urban areas. The advancement in technology can lead to the production of more efficient productions systems. Perhaps, in a distant future, vertical farming would be able to provide food for the entire urban population in a fully automated and sustainable way.

<u>AeroFarms: the most important vertical farming company of the world.</u>

[AeroFarms]() is a sustainable indoor agriculture company based in Newark, New Jersey and uses a patented aeroponic growing system to grow produce. In 2015, AeroFarms started a growing space a 30000 m^2 former paintball and laser tag arena in Newark. In September 2016, the AeroFarms Global Headquarters opened in a 70000 m^2 facility in Newark the largest indoor vertical farm in the world based on annual growing capacity (907 tons per year of leafy greens).

The innovation of AeroFarms is the patented, reusable cloth medium for seeding, germinating, growing, and harvesting they developed. Their cloth medium is made out of BPA-free, post-consumer recycled plastic, which can be fully sanitized after harvest and reseeded with no risk of contamination.

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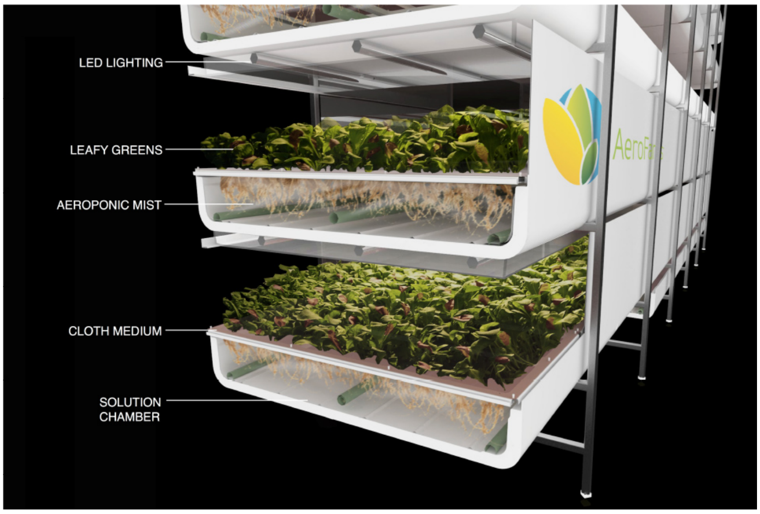

Figure 17. The growing systems of AeroFarms (source: https://aerofarms.com/technology/).

For technical information related to vertical farming:
download The future of farming is vertical or read Plant Factory

CHAPTER 3: Waste and water cycles in the urban context

One of the advantages of make agriculture in the urban context is the possibility to enter in the cycles of urban materials and create new uses, accordingly, enhancing reuse of wastes and by-products. This is primarily true for green waste of the city (which can be used as fertilizers) and water.

3.1. Urban composting

Urban composting is currently booming in connection with urban agriculture programs, as composted organic wastes can be used as fertilizers for plants growth. Organic wastes refer to green garden wastes (dead leaves, hedge clippings, or wilted indoor flowers and plants), animal waste (dung and manure) and degradable kitchen wastes. Composting is the fermentation of organic wastes and comprises 4 phases:

- mesophilic phase: carbon dioxide is released and oxygen is consumed, temperature increases;
- thermophilic phase: the energy contained in organic matter is transformed into heat, and temperature can reach up to 50-60°C;
- cooling phase: temperature drops and fungi colonize the substrate; temperature goes below 30°C and microbial activity lessens bat larger organisms (e.g., compost worms, beetles, centipedes) arrive;
- curing phase: humus forms.

Several benefits are relating to composting process within the urban context:

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- agronomic benefits: compost improves soil structure, water retention, soil plasticity, density and structure; the use of compost increase N, P and K content of the soil, necessary for soil fertility;
- economic benefits: urban agriculture can be considered as a potential market for compost produced in urban setting, reducing difficulties and costs associated with transportation;
- environmental benefits: the production of compost reduces incineration and landfill costs; on the other side, reduces reliance on pesticides and chemical fertilizers; using compost on contaminated soil can considerably reduce the pollutant content, including lead, copper and oil-based products in enriched soil;
- social benefits: the use of compost enhances education and awareness on waste production.

Obstacles to composting.
Composting can be associated by environmental and health impacts. These are mainly related to the fact that compost biomass produces several gases (e.g., N_2O, CH_4, NO_3) which can also have a non-negligible effect on health or the environment. Furthermore, microorganisms which promote the composting process, may cause diseases. Organic pollutants may also be found in the organic wastes out of which compost is produced, which can cause diseases and can be transmitted trough inhalation or ingestion of organic dust particles.

3.2. Water cycle in urban context

UA in a circular city should meet its water requirements by water resources which originate from within the urban watershed, without using available tap water resources. Optimal water resources for UA initiatives comprise natural rainfall, the usa of rainwater temporarily stored in cisterns, or the usage of urban wastewater. The usa of treated or untreated greywater recently received more attention as it also reclaims fertilizer resources such as nitrogen, potassium, calcium, magnesium, sodium and phosphorus. Greywater is defined as wastewater without any contributions from toilet water. The major concerns with greywater reuse have been issues with public health perceptions and inappropriate technology for the reuse option. The amount of greywater produced in a household can vary greatly ranging from as low as 15 L per person per day for poor areas to several hundred per person per day. Factors that account for such huge disparities are mostly attributed to geographical location, lifestyle, climatic conditions, type of infrastructure, culture and habits, among others. Greywater accounts for up to 75% of the wastewater volume produced by households, and this can increase to about 90% if dry toilets are used (**Oteng-Peprah et al., 2018**). Some studies have shown that nutrient-rich wastewater can be productively reused in urban and peri-urban agricultural systems, contributing to crop yield and improving soil fertility, thus enhancing the resilience of urban areas.

Key concepts and vocabulary

CSA: a system that connects the producer and consumers within the food system more closely by allowing the consumer to subscribe to the harvest of a certain farm or group of farms. It is an alternative socioeconomic model of agriculture and food distribution that allows the producer and consumer to share the risks of farming.

Zoning: method of urban planning in which a municipality or other tier of government divides land into areas called zones, within which certain land uses are permitted or prohibited.

Compost: organic matter that has been decomposed in a process called composting. This process recycles various organic materials otherwise regarded as waste products and produces a soil conditioner (the compost).

Hydroponics: The growing of plants without soil. Plants are fed with an aerated solution of nutrients, and the roots are either supported within an inert matrix, or are freely floating in the nutrient solution.

Stocking density: an expression of the number of fishes per unit area or weight of fish per unit of volume of water at stocking.

Biofilter: The component of the treatment units of an aquaculture system in which organic pollutants are decomposed (mainly oxidized) as a result of microbiological activity. The most important processes are the degradation of nitrogen metabolites by heterotrophic bacteria and the oxidation of ammonia via nitrite to nitrate.

Nutrient film technique: hydroponic technique where in a very shallow stream of water containing all the dissolved nutrients required for plant growth is re-circulated past the bare roots of plants in a watertight gully, also known as channels.

Deep water culture: hydroponic method of plant production by means of suspending the plant roots in a solution of nutrient-rich, oxygenated water. Also known as raft/pond or float systems, this method uses floating rafts to suspend plant roots into a pond of water often 10-20 cm deep.

Feed rate ratio: The ratio that helps balance an aquaponics system, relating the amount of feed added to the amount of plant growing area

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Evaluation section

1. An urban CSA is
   - A system that connects producer and consumers, sharing the costs and risks of farming activity, and the products
   - A system of farming products' distribution
   - A system of farming production
2. In order to start and urban CSA activity with 30 subscriptions, how many hectares of land is needed?
   - 0.5 ha at least
   - 15 ha at least
   - 50 ha at least
3. In order to start an urban CSA, main important challenges related to the location are
   - Zoning, soil contamination and water availability
   - Altitude of the place, climatic conditions and water availability
   - Neighborhood acceptation, altitude and soil contamination
4. What makes rooftop farming innovative compared to traditional urban agriculture systems?
   - It uses underexplored urban spaces avoiding soil competition
   - It can be applied with social-educational purposes
   - It can be performed in protected conditions (rooftop greenhouses)
5. Select the right statement:
   - Rooftop farming cannot be performed in open-air conditions
   - Rooftop farming can grow either with soil or soil-less systems
   - Rooftop farming cannot apply household technologies (e.g., recycled containers filled with soil)
6. Before realize a rooftop farm/garden you should define:
   - Rooftop access
   - Cultivated crops
   - Farming goal
7. Image farming purpose is mainly performed by…
   - Agricultural enterprises
   - Hotels and restaurants
   - Non-profit organizations
8. Rooftop farming for innovation aims at…
   - Evolving and ameliorating the sector of rooftop agriculture
   - Offer a pleasant place were to recreate
   - Teaching social and ecological values
9. Urban living quality farming purpose is mainly performed on…
   - Research centers
   - Residential buildings

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- Cafeterias

10. Which of above statements is wrong?
    - Excessive wind exposure may represent a limit for site choice
    - Zoning codes have to be checked before rooftop farm/garden realization
    - A rooftop farm can be realized on every kind of flat rooftop
11. In order to choose the right site for a rooftop farm/garden you have to check…
    - Rooftop loading capacity
    - Building façade
    - Building acoustic insulation
12. The first step you have to take for a rooftop farm/garden realization is:
    - Build the core infrastructure
    - Make a conceptual plan
    - Develop a building plan
13. In a rooftop farm/garden you should avoid to use…
    - Collected rainwater
    - Chemical fertilizers and pesticides
    - Compost
14. Aquaponics is the combination of:
    - Agriculture and aquaculture
    - Aquaculture and hydroponics
    - Aeroponics and agriculture
15. Aquaponics is considered a circular production system because:
    - Water and nutrients discharged from the aquaculture system is lost in the environment
    - Water and nutrients discharged from the aquaculture system may be used to water and feed plants of a productive hydroponics plan
    - Water and nutrients discharged from the aquaculture system may be used for grown other fishes in another aquaculture unit
16. A biofilter is used to
    - Host bacteria which transform ammonia in nitrate
    - Purify the water from residue coming from plants cultivation
    - Purify the water recirculating within the system by environmental pollution
17. The optimal characteristics of a fish tank for an aquaponic systems are:
    - Round shaped, plastic and white
    - Rectangular shaped, plastic and black
    - Round shaped, metal and black
18. A biofilter is not needed in an aquaponic system…
    - When plants are cultivated in a media growing bed and the fish stocking density is low
    - When plants are cultivated in a hydroponic unit with a low stocking density
    - When a mechanical filter is present in the system
19. In an aquaponic system, optimal pH ranges
    - 2 and 4

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- 4 and 6
- 6 and 8

20. In an aquaponic system, optimal dissolved oxygen concentration ranges
    - 0 – 3 mg L^{-1}
    - 4 – 8 mg L^{-1}
    - 8 – 10 mg L^{-1}
21. Feed rate ratio is:
    - The ratio evaluates how much fish feed should be added each day to the system considering the area available for plant growth
    - The ratio evaluates the amount of feed daily assimilated by fishes
    - The ratio evaluates the amount of plants grown into the system
22. The feed rate ratio for leafy vegetables ranges:
    - 40-50 g m^2 day^{-1}
    - 10-30 g m^2 day^{-1}
    - 100-150 g m^2 day^{-1}
23. The volume of the biofilter should be calculated taking into account:
    - The amount of feed entering the system daily
    - The amount of plants grown
    - The number of fishes grown
24. Common species grown in an aquaponic system are:
    - Lettuce and tilapia
    - Tomato and shark
    - Zucchini and catfish
25. Within an aquaponic system, feed the fishes is a
    - Daily activity
    - Weekly activity
    - Monthly activity
26. Within an aquaponic system, water quality tests should be performed
    - Daily
    - Weekly
    - Monthly
27. What is a vertical farm?
    - The cultivation of plants on supporting structures or shelves in an upward direction.
    - The specialized cultivation of climbing plants in vertical trained systems.
    - Type of farming in which farmers cultivate fruit crops either for domestic, industrial or commercial purposes.
28. Where vertical farms are normally located?
    - Rural areas.
    - Urban and peri-urban areas.
    - In fertile lands.
29. Where vertical farms are normally housed?
    - In urban parks and shipping-containers.
    - In supermarkets and shipping-containers.

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- In buildings structures and shipping-containers.

30. What are the main factors to consider when designing a vertical farm?
    - Crop selection, growing medium and its nutrient solution, climate control, food packaging.
    - Crop selection, lighting environment and crop spacing, growing medium and its nutrient solution, climate control.
    - Crop selection, growing medium and its nutrient solution, food transporting, food packaging.
31. What kind of crops are suitable for a Vertical farm?
    - Cereals.
    - Leafy greens and herbs.
    - Root and tuber crops.
32. Which is the most interesting lighting solution of the actual vertical farming market?
    - Fluorescent lamps.
    - High-pressure-sodium lamps.
    - Light emitting diodes lamps.
33. The nutrient solution composition provided to plants should be the same for all crop species.
    - True.
    - False, it can be altered depending on each crop requirement.
    - False, it can be altered depending on climate conditions.
34. The main barrier for implementing a vertical farm is…
    - The need of experienced workers.
    - The high initial investment cost.
    - The high technological management.
35. Which of these ones is an opportunity offered by a vertical farming as compared to traditional one?
    - Less energy required.
    - Avoid crop losses due to weather events or seasonal changes.
    - Big variability of cultivated crops.
36. How vertical farming can be more sustainable?
    - By incorporating renewable solutions to the system.
    - By reducing water consumption.
    - By developing a proper marketing strategy.
37. Which is the last water source that should be used in a urban context?
    - Greywater
    - Rainwater
    - Tap water
38. The structural load of an intensive green roof is:
    - 180-500 kg m^{-2}
    - 60-150 kg m^{-2}
    - 120-200 kg m^{-2}
39. The substrate depth of an extensive green roof is:

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- 60-200 mm
- 120-250 mm
- 150-400 mm

40. Covering material of a rooftop greenhouse should have:
    - Minimum absorbance of the solar radiation
    - Maximum absorbance of the solar radiation
    - Should filter the light

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Activities / exercise

1) By using Google Earth, map the flat rooftop of your neighborhood and try to quantify potential productivity as this surface (follow the methodology reported in **Orsini et al.**, **2014**).
2) Try to size an aquaponic farm (by following the example reported in Figure 13), evaluating the potential productivity. Try also to think to possible market strategy to sell your product.

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Useful resources for the lesson

Allotment Holders Handbook - A guide to allotment gardening

A guide to designing and implementing allotment gardens

How to organize an allotment community garden

The HORTIS project outputs

Seeds's gardening toolkit: building community gardens

Community garden best practices toolkit

Overview of community supported agriculture in Europe

Local Harvest: a multifarm CSA handbook

Good Agricultural Practices for greenhouse vegetable crops

There's something growing in the roof

Small-scale aquaponic food production

Rooftop Agriculture

The future of farming is vertical

https://www.youtube.com/watch?v=HHDgsK09-1k

https://www.youtube.com/watch?v=AmAGgb66IDw

https://www.youtube.com/watch?v=ME_rprRlmMM

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