Different Vertical Farming Constellations

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A. Green Walls (Leen Skaf)

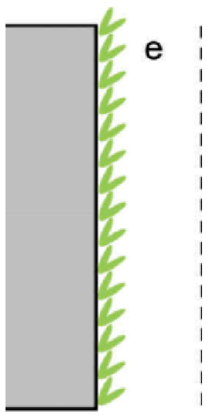

***Fig 1**: Green Walls Structure in Vertical Farming*
Source:https://www.researchgate.net/figure/Representation-of-vertical-farming-VF-types-Stacked-horizontal-systems-comprise_fig1_331130061

Green walls are vertical structures of the many constellations of vertical farming (VF) that usually have various plants attached. The growth medium is the surface of a wall building, vertical or inclined, composed of soil, stone, or water. It could be indoor or outdoor installations. Green wall structures often use built-in irrigation systems and can be pre-grown. According to the pilot study, these living walls can also provide regulating, provisioning, and supporting ecosystem services, regulating services such as enhancing air quality, provisioning services like giving energy output and supporting services like sustaining quality habitats and species diversity (Nagle et al., 2017). One of the most significant advantages of green wall structures is to supply extra space to grow food where arable land is unavailable or expensive. Furthermore, smart and active green walls play a big role in purifying the surrounding air with air circulation systems (Mustonen, 2017). However, the downside of this is mainly the initial investment costs and some setup challenges. Since it is a relatively newly-adopted technology in VF, the costs to design those urban green wall buildings are expected to be high. A further disadvantage is the ease of harvest and maintenance of a green wall. Growing food crops that need high maintenance regarding water, fertilizers, and light, green walls would not provide the best option for VF structures. Balancing water and light availability from the top of the building to the bottom of the building is quite tricky. The roots at the bottom tend to dehydrate because they do not receive enough water, whereas the roots at the top tend to rot. After all, they receive too much poorly drained water in a green wall system (Bosque, 2021).

Another factor to consider when selecting the location and the dimension of a green wall is the availability of light. The PAR level is the measurement of photosynthetically active radiation in micromoles/sec-m² (Storey, 2016). The building height and orientation influence it; as claimed by M. Beacham et al., east-west oriented buildings are better for continuous cultivation because, in this way, the effects of sun oscillation from north to south are avoided. Additionally, potential risks due to urban pollution exposure, variant light availability from top to bottom stories in the building, and providing balanced water to all levels might put many obstacles in executing these VF constellations (M. Beacham et al., 2019).

Outdoor green walls usually do not require seasonal energy input to control the growing conditions such as light, temperature, but it needs irrigation water systems. Sometimes, constant nutrient-rich water irrigation is required during dry, hot seasons, which is economically not attractive. Hence, ecosystem services are constrained by light and temperature variations in different climates (Nagle et al., 2017).

Green walls have some potential in producing certain vegetable species on a small scale, as the productivity rates can be predicted based on average solar exposure, temperature, and soil moisture levels of urban land. The daily consumption of leafy vegetables can be supplied using these green wall systems, saving space and costs of extra land for that purpose (Nagle et al., 2017). However, using green walls for aesthetic benefits might be the safer option because species like succulents do not require high maintenance of water and nutrients. They suffice with the minimum supplies, which prevent the risk of rotting plants at the top or dehydration at the bottom of the building (Bosque, 2021).

B. Balconies (Adiel Batson)

Balconies are a residential solution in vertical farming systems. It is an alternative to multi-floor towers. As a residential product, yields and output are significantly lower than other commercial methods. Nonetheless, the method is an excellent tool in strengthening food security and self-sustenance for those with minimal access to capital and space interested in growing food and/ or hydroponic systems (Beacham et al., 2019). Some great pros of this method include:

- low carbon footprint in transporting food between consumer and producer
- lower complexity than other hydroponic systems in managing a smaller space
- efficient space use in urban environments
- helps offset food demand by influencing local food security in urban environments.
- comparatively low initial investment to start.

Some considerable negatives of the system are:

- Lower crop yields and outputs compared to other vertical farming methods.
- Considerable complexity in tandem with the scale of operation.

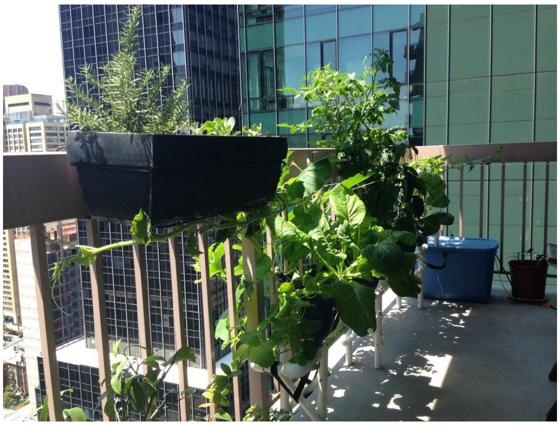

Fig 2*: Balcony hydroponics*
Source:
https://www.instructables.com/Urban-Gardening-Balcony-Hydroponics/

C. Shipping containers vertical farms (Daphne Larose)

Shipping container vertical farms provide an alternative to conventional farms, especially in urban areas without easy access to arable land. This new type of plant production system of refurbished shipping containers with a controlled environment including elements such as LED lights, drip irrigation systems, vertically stacked shelves, and computer-controlled monitoring systems that permit remote access through a smartphone or a computer and optimize the growth conditions. These vertical farms are often based on soilless cultivation techniques. The most common techniques are hydroponics, where plants are grown in nutrient solutions free of soil; aeroponics, in which plants grow in an air/mist environment with no soil and very little water; and aquaponics that combine plants and fish in the same ecosystem. The fish are grown in indoor ponds and produce ammonia. The water containing ammonia is then used as a nutrient source for the plant. The plants purify the water, which is then recycled to the fish pond. (Birkby, 2016)

The shipping containers vertical farms offer many advantages. First of all, containers are readily available, and shipping companies are often willing to sell containers that can no longer be used for their original purpose at reasonable prices. The controlled environment of the containers allows for clean and insect-free cultivation; 80% fewer fertilizers and pesticides are used compared to conventional farms. (Birkby, 2016) The water consumption is also drastically reduced by up to 95% by operating closed-loop irrigation systems that collect, recycle and reuse water vapor from evapotranspiration from the plants, unlike conventional greenhouses where the water is lost due to ventilation processes.(Avgoustaki & Xydis, 2020) Another important advantage of indoor vertical farming is the remarkable land use reduction and increase in yield owing to several layers of stacked plants and constant monitoring and control. Optimum conditions for plant growth are created. For example, fans are installed to allow proper air circulation to improve photosynthesis and transpiration. Artificial lighting provides the necessary nanometers of the spectrum for the growth and development of plants. Considering that plants require hours of daylight and fewer hours of darkness, it is easier for farmers to select the hours when electricity prices are at the lowest as daylight hours and darkness at times during the day when the prices are high. (Avgoustaki & Xydis, 2020)

However, this type of vertical farming tends to have high operational costs. The three major operational expenses are the electricity cost with 25–30% of the total cost; lighting accounts for about 80%, air conditioning 16% and 4% is for the auxiliary equipment, the operational costs with 27% of the total cost and the capital expenditures with 18–20% of the total cost. (Avgoustaki & Xydis, 2020)

***Fig 3**: Container vertical farming from Flexifarm in Thailand*
Source:
https://www.verticalfarmdaily.com/article/9358471/the-first-company-to-provide-shipping-container-farms-in-thailand/

D. Cylindrical Growth Units (Kshama Gauri)

Cylindrical growth units come under the umbrella term of vertical growth surfaces. In this system, plants are grown vertically above one another in an upright cylindrical format, as shown in figure 3. The nutrients are supplied within the cylinder as soil or using a hydroponic system. These plants are usually grown in a greenhouse or a controlled environment(CE). (Beacham et al., 2019)

Pros:

- Higher crop productivity (ratio of yield to growth space) is seen in the cylindrical growth unit. (Touliatos. et al., 2016)
- Could make optimal use of growing space. That is, it can grow more plants per unit area than horizontal farming. (Touliatos. et al., 2016)

Cons:

- It increases the risk of hypoxia in plant roots. (Touliatos. et al., 2016)
- Higher plant density can impose intense interspecies competition for light and nutrients within the growth unit. (Touliatos. et al., 2016)
- Gradient productivity of the plants decreases in contrast to a horizontal hydroponic system where it is stable. This is due to the dependency of the plants on light. (Touliatos. et al., 2016)

Ways to overcome the disadvantages :

- Develop an efficient spacing technique to avoid competition and ensure there is no limit to plant growth.
- Ensure the structure receives an equal and sufficient amount of light from the top to the base.

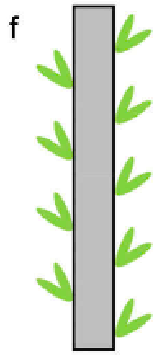

***Fig 4**: Cylindrical Growth Units in Vertical Farming*
Source: (Beacham, et al, 2019)
https://www.researchgate.net/figure/Representation-of-vertical-farming-VF-types-Stacked-horizontal-systems-comprise_fig1_331130061

E. Vertical Farming Tower (Yongyi Wang)

The vertical farming tower is one of the most common and easy constellations of vertical farming. It is a hydroponic or aeroponic (growing plants with only water and nutrients) system. This constellation can yield 35% to 50% more than soil-based organic farming, save 95%of water and save 90% of space. (Agrotonomy, 2018) Aeroponic growing systems are clean and fast for food production. Since there is no soil involved, there will be no weeds, pesticides, or soil-borne disease.
Moreover, it is a small system; it can be used anywhere with sunlight and is easy to construct. Besides, the mineral nutrients can be easily modified to specific plants, improving the quality and yield of the crop. (Richard, 2014) However, it needs regular cleaning to keep the reservoir free from bacteria, and also it is not ideal for all kinds of plants.

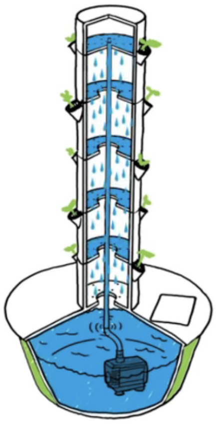

Fig 5: The structure of the tower
Source:
https://www.canopycolumn.com/

In this constellation, it contains a base which is a small reservoir. Water and other nutrients needed for growing the plants will be stored in the reservoir. Another important part of the reservoir is the small submersible pump. The pump will then push the water and nutrients up to the top of the tower. The water and nutrients will then cascade down through the tower and feed the roots of the plants. (Agrotonomy, 2018)

F. *Multi floor tower farming (Rajshree Jeewon)*

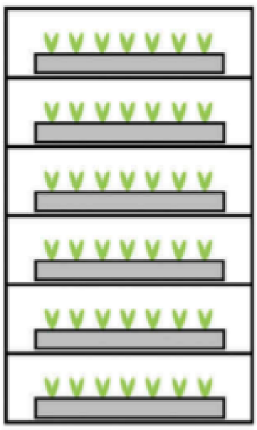

***Fig 6**: Multi-floor-tower farming structure*
Source:https://www.researchgate.net/figure/Representation-of-vertical-farming-VF-types-Stacked-horizontal-systems-comprise_fig1_331130061

Multi-floor-tower farming is a variation of the stacked horizontal systems. Each level of planting is isolated from the surrounding levels, as can be seen from figure 5 (placed on different floors of a tower structure), unlike others where various plant growth levels are located in the same glasshouse or controlled environment (M. Beacham et al., 2019). This type of farming enables the versatile conditions for each level of planting to be maintained, which allows a broad range of crops to be grown by adjusting the conditions that better suit each crop at every level. These farms come with significant advantages such as a stable crop yield as the plants are grown in a computer-controlled environment with 24h LED lighting, air humidity with 30 percent carbon dioxide enrichment, and nutrients. Moreover, the production is 100% sterile with no pesticides used and germs (Tamar Haspel, 2016). Also, the growth of plants is protected from seasonal weather patterns, and there are fewer crop losses.
Nevertheless, multi-floor-tower farming does come with some drawbacks. It requires a high upfront cost and remarkable operational costs. Significant efforts have to be made for the maintenance.

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