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REGULAR ARTICLE

Vertical farm: prospects for achieving sustainable development goals

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Abstract

The objective of this study was to demonstrate the importance of the vertical farm as an alternative for the supply of food to the world population, mainly, in the countries where the scarcity of land is evident. We linked the use of the vertical farm with the objectives of sustainable developments developed by United Nations (UN) in the fight against hunger and social inequalities in the world. A search was carried out in the databases Pubmed, Web of Science and specialized sites, using the words, vertical farm, fight against hunger and food production. According to the articles found, we could conclude that the use of the vertical farm can bring great advances in improving the supply of food to the low-income population; however, there is a need for budgetary adequacy for the implementation and operation of the entire system, being that in in some cases the costs are very high. This causes a certain skepticism in its viability. The collaboration of government agencies, non-governmental organizations and private initiative with financial support for the creation of vertical farms is essential

Keywords

Vertical farm; sustainable development objectives; lack of food; hunger; agriculture.

Introduction

World hunger is a constant concern of international entities, such as the United Nations (UN), which in 2015 proposed to its member countries a new sustainable development agenda for the next 15 years, the 2030 Agenda, comprising the 17 Sustainable Development Goals (SDGs) in order to reduce inequalities and contribute to equitable living conditions in the world (United Nations, 2022).

The 2030 Agenda seems to mobilize many nations to contribute and implement actions that aim to improve the planet, as well as the lives of people in greater economic and social vulnerability.

The expectation of the world population in 2050 is around 9.7 billion people, 70% of which will live in urban areas (United Nations, 2015), in addition, almost half of the current population lives below the poverty line, that is, less $ 5.50 a day in low-income countries (Banco Mundial, 2018). With this significant increase in population, there is also a growing need to supply the demand for food and this may become a problem in face of the scarcity of land available for agricultural cultivation (Silva & Barbosa, 2020).

In this context, we can include the use of vertical farming as an alternative to the scarcity of land for planting food, considering that it needs a much smaller area for food production.

There is discussion about whether there is really a lack of food in the world or there is a difficulty in its distribution (Tonial, 2009), as suggested by Peter Singer who emphasizes that: “if we stopped feeding animals with grains and soy, the amount of would be saved - if it were distributed to those who need it - more than enough to end hunger worldwide”.

Anyway, there is a need for food production to be sufficient to meet the world demand, both for animals and humans, and for there to be enough land for such an act.

An alternative appears that aims to fill the lack of agricultural land, the vertical farm, which is a model of agricultural production inside buildings, this is different from indoor agriculture, since the quantity supplied can support cities with their own resources (Gianezini et al., 2016). According Despommier (2011) this vertical and controlled environment emerged as a response to an inadequate roof garden model, which was made up of a very limited size.

There are two types of indoor farming: greenhouse and vertical farming. Vertical farming emerged as a strategy for optimizing the use of resources and land use (Eldridge et al., 2018).

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Growing plants in the vertical irrigation direction is defined as vertical farm and can use artificial or natural light. This system is generally uses soil-free and hydroponic growing environments or aeroponic irrigation technology (Benke & Tomkins, 2017).

We can describe three types of vertical farming. The first is described with the construction of tall structures with several levels of beds and possibly artificial lights. The second occurs on the roofs of old and new buildings, on top of commercial and residential structures, as well as in restaurants and grocery stores. The third is that of the multi-story building. There is a growing increase for this proposal, but none built (Despommier, D, 2014, Touliatos et al., 2016, Muller et al., 2017).

The stacked horizontal systems, represents in Figure 1(a, b), frequently adapts existing commercial protected horticulture systems. Such systems comprise multiple levels of traditional horizontal growing platforms. Multi-story towers are a variation of Stacked Horizontal (Figure 1(c)). This system includes multiple levels of plant growth, which takes place in the same chamber at different planting levels, located on isolated floors of a tower. Multi-Floor Towers is the use of balconies for growing products (Figure 1(d)). This approach is best suited for individual or community production rather than commercial companies. Green Walls are vertical or inclined grow towers located in places such as the facades of buildings (Figure 1(e)). Cylindrical growth units are systems in which plants are grown one above the other around the surface of vertical cylindrical units capable of house a nutrient supply (soil or hydroponic substrate) and located within a greenhouse or control environment facility (Figure 1(f)) (Beacham et al., 2019).

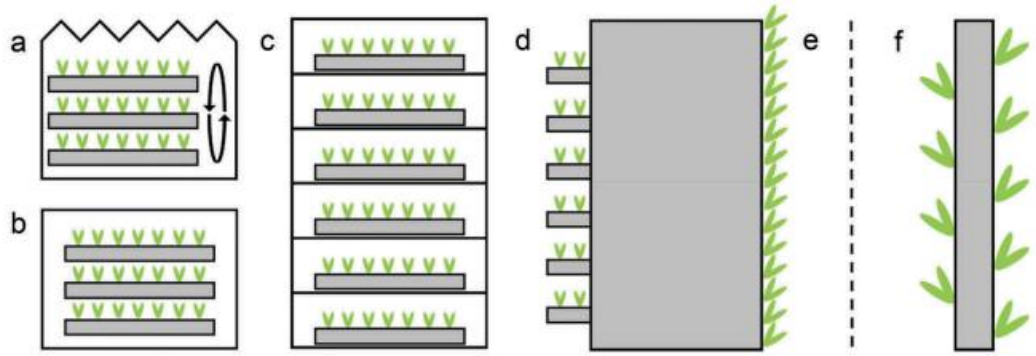

Figure 1. Representation of vertical farming (VF) types. Stacked horizontal systems comprise multiple levels of horizontal growing surfaces and can be located in glasshouses (a), sometimes with level rotation incorporated, or controlled environment (CE) facilities (b). A variation of this approach is that of multi-floor towers (c) where each level is isolated from the surrounding levels. The use of balconies (d) for crop production is another example of VF using stacked horizontal growing surface. Vertical growing surface include green walls (e), which can be positioned on the side of buildings and other vertical surfaces and cylindrical growth units (f) with vertical arrangements of plants Beacham et al., 2019.

Vertical farm can be a strategy to achieve the goals of sustainable development, advocated by the UN, to end poverty, promote prosperity and well-being for all, in addition to protecting the environment and facing changes climatic (Cicekli & Barlas, 2014).

In order to contribute to the sustainable development goals, developed by the UN, agricultural engineering and agronomy can enable strategies aimed at supporting food for humanity, as these are areas that strive to improve equipment and supplies for planting, harvesting and storage.

The purpose of this article was to show the importance and contribution of agricultural and agronomic engineering, through vertical farms, in fighting hunger, technological innovation and responsible production in accordance with some of the sustainable development objectives established by the United Nations.

The use of the vertical farm can contribute to the improvement of agricultural strategies in increasing food production in a smaller amount of land. For this reason, we emphasize the importance of researching the topic in order to find the real contribution of this technique, in addition to its sustainability and economic implications.

Materials and methods

A bibliographic survey was carried out in the databases Pubmed, Web of Science and specialized sites, from June 2020 to May 2021. The words: vertical farm, sustainability, hunger, economy and agriculture were used.

Articles that showed the benefits of using the vertical farm were included, as well as their indications, implantations, risks, difficulties, costs and facilities. Our objective was to verify if there is a possibility of using the vertical farm in some of the UN Sustainable Development Goals.

From the 17 SDGs, we chose three that could benefit most from using the vertical farm in food production, reducing hunger, healthy eating, producing food in a sustainable way, using adequate infrastructure, innovation, inclusive industrialization and resilients.

We found two articles that emphasized the importance of engaging small farmers in food production and fighting hunger, thus being able to collaborate in SDGs, but not with emphasis on vertical farms (Mashaba-Munghemezulu, et al, 2021, Vamuloh, et al. 2019).

Faced with the scarcity of articles that relate the vertical farm with the SDGs, we proposed to describe the use of the vertical farm as a strategy that could collaborate in the SDGs, not leaving out its limitations.

When we used the descriptors vertical farm and SDGs we found only 2 articles (Didenko et al., 2021 and Ares et al., 2021) that addressed the subject. Despite this limitation, we included references that addressed the vertical farm and those that addressed the SDGs, as our objective was to describe the feasibility or not of vertical farms in some SDGs of the UN Agenda 2030.

Results and discussion

When we used the vertical farm descriptor and SDGs, we found 23 articles, but when reading the texts, only two articles relate the descriptors. The other 21 articles describe only one of the descriptors, either vertical farm or SDGs. Even so, some were used because they were related to the subject.

We selected the articles and texts that contemplated the research objectives. The following are the considerations on the relationship between the use of the vertical farm and three of the sustainable development objectives elaborated by the UN. We try to explore both the positive and negative aspects for the implementation of the vertical farm as a way of sustainable food production.

About sustainable development goal 2:

This goal is entitled "Zero Hunger and Sustainable Agriculture", with the aim of ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture. some items are listed to be achieved in this objective, such as:

"- end hunger;

- end all forms of malnutrition;

- doubling agricultural productivity and income for small food producers;

- guaranteeing sustainable food production systems and

- implement resilient agricultural practices, maintain the genetic diversity of seeds, cultivated plants, livestock and domesticated animals" (United Nations, 2015).

In this item, of the sustainable development goal, we see the importance of planning strategies from the vertical farm. Perhaps this is the item to which the vertical farm can contribute most emphatically.

With the increase in the world population, it´s necessary a 70% increase in food production by 2050 is estimated (10), so to meet the need for an average of 1500 Kcal per day, an area the size of Brazil would be needed to supply this agricultural demand (Despommier, 2011).

The production capacity of vertical farms varies according to the area of the buildings in which they are located, but there is a clear lack of space to increase production. This statement is in line with the principle of vertical farms, which is to produce more food on less land (Touliatos et al., 2016; Muller et al., 2017), using advanced technologies and innovative methods of agriculture (Al-Kodmany, 2016).

These characteristics of the vertical farm can contribute to the sustainable food production system, as well as implement agricultural practices that adapt to changes in climate and soil, contributing to increased productivity, this can lead to access to food for the poorest people and decrease malnutrition. Undoubtedly, the reduction of hunger is extremely important, but we have to transform the optimism of the vertical farm into reality.

The food produced by vertical farms can have very attractive prices, as they are located in urban areas, which would allow direct sale to the final consumer, removing the middleman and transportation costs (Al-Kodmany, 2016). An

example is Brazil, where 85% of the population lives in the urban area, emphasizing the importance of access to crops in these areas.

The advantages of the vertical farm can be described in several aspects, such as: low energy use, low labor costs, low water use, reduced transport costs (Advantages, 2017), increased productivity, tasty vegetables, production throughout the year, consistent and reliable harvesting, easy to install and easy to maintain (Sky Greens, 2022), energy conservation, reduction of fossil fuel, reduction of Global warming, improvement of biodiversity, brings socioeconomic benefits to the community and improves nutrition and health (Cerón-Palma et al., 2016).

All of these advantages seem to be the best scenario for the implementation of vertical farms and to contribute to sustainable development to eliminate hunger on the planet. However, it is necessary to assess regional aspects, as well as the costs for implementing this type of agriculture, in order to make it promising alternative to fight hunger.

Consumers show positive attitudes when asked about the vertical farm, but there is a small group that remains neutral or has a negative evaluation of the vertical farm. It is necessary that the population be exposed to the pros and cons of the vertical farm (Ares et al., 2021).

About sustainable development goal 9:

This goal aims to: "Build resilient infrastructure, promote sustainable industrialization and foster innovation", within this important aspect emerges the technological innovations of agriculture, through vertical farms, as they emerged with the purpose of innovating in food cultivation.

Vertical farms can be to facilitate the development of sustainable and resilient infrastructure. As described by Nadal et al. (2018), he suggests the implementation of greenhouses on the roofs of schools that are well located, which contribute to the sustainable development goal 9, also meets the recommended by sustainable development goal 11. This turned the cities more inclusive, safe, resilient and sustainable. This research shows in detail how to proceed with the elaboration of the so-called “rooftop greenhouses”, strategies that can be done in small spaces, with about 50 and 100m², making it viable and sustainable.

The farms are designed in controlled environments with ideal exposure to adequate light and nutrients, with this rigor, in the control of environments, there would be no need for harmful herbicides and pesticides, maximizing nutrition and the value of food (Nadal et al., 2018). These systems (mainly hydroponics, aeroponics and aquaponics) and associated technologies are evolving rapidly, diversifying and improving (Al-Kodmany, 2018). The need to produce more research is visible so that these systems can be implemented anywhere and provide greater production and less environmental impact.

Greenhouse technology must be transformed into a vertical farming system, but for this to happen, research and projects that address such development are necessary (Cicekli & Barlas, 2014).

Some authors understand that vertical farm technology is based on high-income countries, but that there is great potential to benefit low-income people, and can provide important micronutrients in their nutrition. Public funding for the development of these technologies is still small, which hinders the development and implementation of the vertical farm (Dolgin, 2019; Beacham et al., 2019).

Vertical farm and greenhouse models can collaborate in arctic areas, collaborating in the economy, since cultivation in open areas generates poor quality and high cost products. In this way, vertical agriculture would be a solution to these problems (Didenko et al., 2021).

Technological innovations must be accessible to all countries and not just to rich countries, and such access could improve local infrastructure by making healthy food available.

Vertical farms can be involved in hydroponic agricultural production, Aeroponics and aquaponics, showing their great diversity.

About sustainable development goal 12:

This goal is entitled “Responsible consumption and production”, the objective is “Ensure sustainable consumption and production patterns”, and we will discuss some benefits that the vertical farm can contribute to sustainable management, the reduction and reuse of waste and reduce waste.

There are alternatives that reduce food waste, such as a fertilizing and composting sector, that aim to reuse food. Another alternative would be the donation of food to institutions, agencies and social projects that aim to help people in a state of social vulnerability (Barros & Alves, 2020).

Through the waste generated by vertical farms, energy generation can be obtained through the anaerobic fermentation of organic materials, which results in the burning of biogas (Despommier & Ellingsen, 2008).

The most relevant aspect of these sustainable development goals is the ability to create strategies, infrastructure and mechanisms for the reuse of waste generated from planting waste and consumer food waste.

The need for models in agricultural production is clear, since population growth and climate change are notable without relent. Thus, the vertical farm can become a strategy, of the scientific community, to guarantee food security, despite the lack of conclusive data to affirm its economic viability (Silva & Barbosa, 2020).

Therefore, it is important to highlight the efforts of the academic community to find models that integrate efficiency in production, energy consumption and financial results.

Conclusions

The vertical farm model shows promise in combating hunger, energy production, reducing waste and sustainable investment, making it subject to future research and investments.

The sustainable development goals created by the United Nations aim to make the world fairer and more accessible to the most disadvantaged people, thus access to food can greatly reduce such inequality.

In the production of healthy foods that are available to the entire population is agricultural and agronomic engineering that with tireless research tries to find models that make this premise viable.

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