



## ARE VERTICAL FARMS SUSTAINABLE?

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### YOUNG REVIEWERS:



ALISSAR

AGE: 14



YASH

AGE: 12

Today, cities are growing—taking up more space and filling up with more people. The growth of cities reduces the Earth's natural resources and the amount of land available for farming. As Earth's population grows, food production must increase so that everyone will have enough to eat. Vertical farming is a type of farming that can be done within cities, in spaces like empty buildings. In these indoor spaces, conditions (temperature, water, etc.) can be controlled so that food can be produced all year round. In vertical farms, the drained water can be recovered and reused. Lots of plants can be grown in small spaces. Despite these positive qualities, artificial lights must be used because there is no sunlight, so unfortunately a large amount of energy is needed to run vertical farms. As lights become more efficient, vertical farms can be a sustainable, environmentally friendly way to produce food.

## URBAN AGRICULTURE

Methods for cultivating food within cities, towns, and within buildings.

## SOILLESS SYSTEMS

Methods of growing plants without soil, which include hydroponics and aeroponics.

## SUSTAINABLE

When a process uses resources efficiently and has a healthy relationship with the natural environment, for example recycling water or consuming less energy.

### Figure 1

In a vertical farming system, plants grow in trays stacked up on shelves. These trays may have a little soil in them, to support plant growth, or no soil at all—making watering the plants very efficient. Each shelf has LED lights, and a mix of red and blue light is often used. Combined, these colors make a pinkish light that plants can use to perform photosynthesis and grow.

## WHAT IS A VERTICAL FARM?

Today, cities take up large amounts of space on our planet, reducing the amount of land available for farming. At the same time, the huge numbers of people that live in cities use up a lot of natural resources. As the human population continues to grow, we must increase the amount of food being produced so that everyone has enough to eat. **Urban agriculture** is a type of farming in which food is grown inside cities. Urban agriculture can help to prevent hunger and it might be better for the environment than traditional farming. Vertical farming is a novel type of urban agriculture that first appeared in the late 1900s in the US, Japan, and the Netherlands. As advances in technology were made, vertical farming expanded [1, 2].

Vertical farming is a type of food-production system in which food is grown in an indoor environment where growing conditions like temperature, light, and humidity can be controlled. In cities, empty buildings or warehouses are perfect for vertical farming. Smaller vertical farms also exist for small-scale food production, for individual households, restaurants, schools, or shops, for example [3]. In vertical farms, plants do not grow the same way they do on traditional farms. Instead, they grow in trays without soil, stacked on shelves (Figure 1). This **soilless system** allows lots of plants to be grown in small spaces where the conditions can be kept just right. In a vertical farm, up to 80 g of fresh lettuce can be grown with 1 L of water. In an open field, only 20 g of fresh lettuce can be grown with 1 L of water! The amount of food grown in vertical farms can be up to 200-fold higher than in open fields [4]. This means that vertical farming can be a **sustainable** way to grow plants in cities.

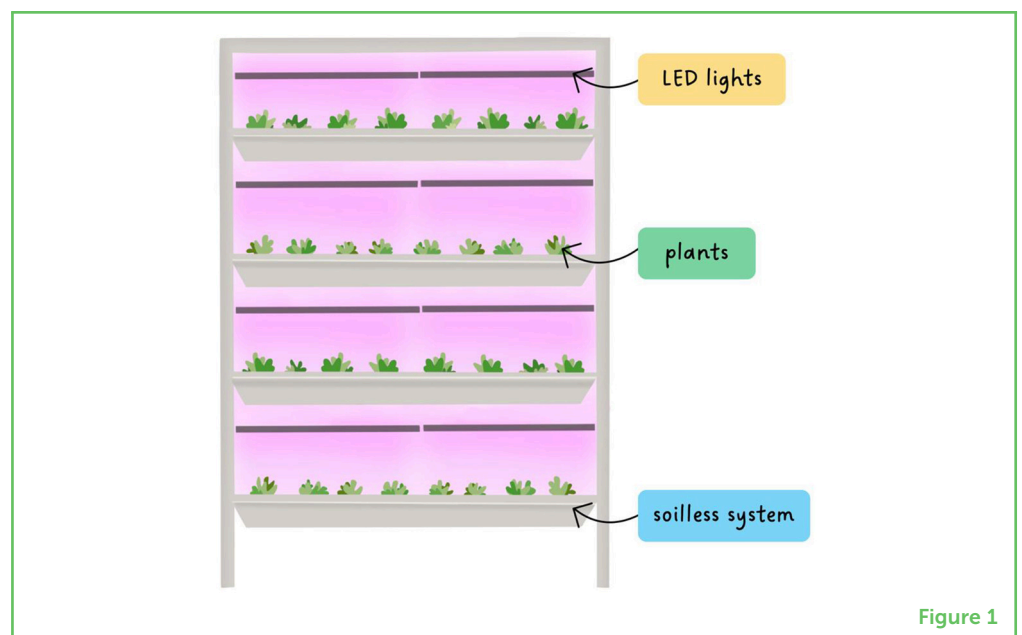


Figure 1

## WHAT DOES A VERTICAL FARM LOOK LIKE?

Inside a vertical farm, you can find plants, artificial light, a water source, and a stable climate. Vertical farms use artificial light, such as the light produced by LEDs, to imitate the sun. LEDs are the most energy-efficient lights available, and they come in many colors: red, blue, green, white, and far-red (which plants can use but humans can barely see). More colors can be made by mixing LEDs. In fact, a mix of red and blue light is the most common combination for vertical farming, because those are the colors plants mainly use for **photosynthesis**—a process that is needed for plant growth [5, 6]. With LEDs, farmers can choose the perfect light recipe for each plant species, including the exact colors, the intensity of the light, and how many hours of light the plants get. With the perfect light recipe, the best plant growth can be achieved. Even though LEDs are quite expensive, their lifespan is longer than other types of lights.

As we mentioned, plants in vertical farms grow in soilless systems. The nutrients plants need are added to the water and delivered using two main types of **irrigation**. In a **hydroponic** system, plant roots are submerged in tanks filled with nutrient-containing water, either constantly or only a few times per day, depending on the type of hydroponic system used. In an **aeroponic** system, plant roots are sprayed with nutrient solution, for example for 1 min between four and six times per hour, to avoid dryness. Both of these systems use less water than is needed for growing plants in soil. In either system, pots containing peat or organic sponges can be used to support the plants and keep them wet all day (Figure 2).

Through the process of **transpiration**, plants also release water through small openings mainly located on their leaves, called stomata. In vertical farms, this water can be recovered and reused for watering plants.

When plants are grown inside closed spaces, the climate can be controlled. In vertical farms, all the conditions are regulated and are independent from the conditions outdoors. For example, constant air temperature and air circulation are important. Humidity (the amount of moisture in the air) must also be controlled. Carbon dioxide can also be added inside the structure, to help plants with photosynthesis. Within these controlled spaces, plants can be grown every day of the year, regardless of weather or seasons.

In vertical farms, mainly leafy vegetables, medicinal plants, or small seedlings are grown—like lettuce, basil, or rocket. These plants are not as tall as other vegetable plants, so they can easily grow in the shelves. They also grow quickly and close together, and they do not need intense light. Lastly, they can be sold for a good price. For all these reasons, these crops are the most suited for vertical farms [3].

### PHOTOSYNTHESIS

The process by which plants use light to produce the food they need to grow, together with carbon dioxide and water.

### IRRIGATION

The process of applying water to plants to help them grow.

### HYDROPONICS

A growing system in which nutrient-containing water is delivered to hanging plant roots as they grow inside a tank, or to plants growing in pots with soil.

### AEROPONICS

A growing system in which nutrient-containing water is sprayed directly onto naked, hanging roots.

### TRANSPIRATION

The process by which part of the water absorbed by plant roots is released by leaves and stems through small holes called stomata.

## Figure 2

Two main soilless systems are used in vertical farms. In a hydroponic system, plant roots are immersed in water containing the nutrients plants need. Roots can be immersed for a few minutes several times per day, based on the plant's needs and growth stage. Sometimes just a little soil is used to keep plants wet and stable. In an aeroponic system, plants' roots are exposed and frequently sprayed with a nutrient solution. Plants can be supported using plastic pods and organic sponges.



Figure 2

## IS A VERTICAL FARM SUSTAINABLE?

To determine whether vertical farms are sustainable, we must consider all the resources used in the system: water, energy, and space. Agriculture uses almost 70% of the fresh water available on our planet [4]. In vertical farms, the efficiency of water usage is improved compared to traditional farming, where water is often lost in the soil. In fact, a study demonstrated that vertical farms have a higher water-use efficiency for many plants, such as basil and lettuce [5, 6]. This means that the mass of plants produced per unit of water used is higher in soilless systems with a stable climate, optimal light, and reuse of transpired water.

The choice of empty city spaces for vertical farms helps natural ecosystems because less land must be used for farming. Stacking the plants on shelves means more plants can fit into a space, producing more food in a smaller area.

Unlike open fields or greenhouses, there is no sunlight in vertical farms. Lamps are the only light source, and these farms need a lot of energy. Controlling the climate within vertical farms requires energy, too. The energy use of vertical farms is one of their major limitations. The world needs new strategies to improve the energy efficiency of vertical farms. LED lamps help, because light colors and lamp heat can be adjusted to obtain the best plant growth and energy efficiency. Solar

panels may be able to provide a “green” energy solution, but further studies are needed [4].

## THE FUTURE OF VERTICAL FARMS

In summary, researchers have been working hard to find the best indoor food-growing solutions for cities. Vertical farms are a good option because lots of plants can be grown in a small space, no pesticides are needed, and food can grow all year long. Farms located in cities also reduce the distance that food must travel between where it is produced and where it is eaten—and this is good for the environment, too. However, a lot of energy is needed to provide the light plants need and to control the climate in vertical farms. Reducing the energy use of vertical farms is a top priority, and more research is still needed. We hope that, in the future, growing food in vertical farms will support the world’s food system in a sustainable way, helping to feed Earth’s growing populations while keeping the planet healthy.

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## YOUNG REVIEWERS



### ALISSAR, AGE: 14

Alissar is a student in grade 9, known for her iconic portrayals of contemporary life, which have alternately been described as surreal and hyper-realistic. Widely considered to be one of Syria's child artists, trained at the Traditional Crafts of Syria. Alissar also worked for a children's radio programme called The Argonauts, as a presenter on SY-TV's Children's Hour, and as a drawing and art talent at the National Art School and The *Martyr Basil Al-Assad School*, Damascus, the *Syrian Arab Republic*.



### YASH, AGE: 12

I am a curious middle-schooler with a wide range of interests in math, science, music, tennis, geography, and building large lego sets. I love volunteering at a local animal rescue and write their monthly youth newsletter. I play the drums, and am learning to play many other percussion instruments in my school band. I am considering being a lawyer when I grow up because I am getting good at presenting a fair argument with my parents.

## AUTHORS

### ILARIA ZAULI

I am a Ph.D. student at the University of Bologna, currently studying aeroponic and hydroponic systems in vertical farms. Since I was a child, I have loved nature and flowers, and I also developed an interest in climate change and sustainability issues. For this reason, I decided to study biology and natural sciences, including the field



of urban agriculture. I believe that sustainable food production in cities can be the solution for the challenges our planet will face in the future.



### **GIUSEPPINA PENNISI**

I am a junior assistant professor at the University of Bologna, in Italy. During my Ph.D. work, I studied how light can influence plant growth and metabolism, and how artificial light can be efficiently used for growing plants in indoor environment. I strongly believe that food production should take place closer to where food is consumed, which is why I have always been fascinated by urban agriculture.

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