What if we grew plants vertically?

By 2050, an estimated two thirds of the world population will live in urban areas. Could vertical farming help feed this growing urban population sustainably by reducing the demand for agricultural land and shortening the travel distance between food production and consumption?

Vertical farming is the practice of producing food in vertically stacked layers or vertically inclined surfaces, sometimes integrated into buildings, without soil or sunlight. The food produced consists primarily of leafy green vegetables, fruits and herbs, such as lettuce, spinach, kale, tomatoes, peppers, strawberries and basil, but not cereals or legumes such as wheat, rice, corn or soy. The plants are grown in hydro- or aeroponic systems, meaning that they are suspended in water or air/mist and receive all their nutrients via this medium. Aquaponic systems combine hydroponics and aquaculture. Methods of controlled-environment agriculture (CEA) are used to manage humidity, temperature, gases, light (amount and wavelength), nutrients, acidity level, carbon dioxide, water and pathogens.

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The promises of vertical farming are plenty: year-round, predictable production, independent of weather, season or climate (and therefore climate change) and consequently without large seasonal price fluctuations. A short chain between producer and consumer would drastically reduce food miles and result in fresher, more nutrient-rich produce. Vertical farming could attain higher yields while requiring considerably less water and pesticides or herbicides. It is even possible to alter the nutrient content and flavour of the plants by controlling the growth medium. The bottlenecks slowing down the full-scale application of vertical farms are their high energy demand and related environmental sustainability issues, efficiency of the light use by the plant, and the high start-up and scale-up costs. Will growing food vertically be a distinctive feature of the urban architecture of the future?

Potential impacts and developments

Vertical farming is connected to urban farming initiatives. The idea that food could be grown in stacked layers is being tried and tested all over the world, from New Jersey (US), to Belgium, and from Dubai to Japan, and researchers are also looking into the efficiency of vertical farming. Future developments may bring about kitchen cupboard-sized vertical farms for home gardening enthusiasts or vertical farming aisles in local supermarkets. On a larger scale, by re-using and repurposing empty warehouses, factories and plants, vertical farming could play a role in the reconversion of industrial areas, though this may first involve restoring contaminated land.

While it is in theory possible to grow practically any crop vertically, the most cost-effective are fast-growing crops with little or no inedible parts like roots and stems and with high market value. The technologies underlying such soilless farming in strictly controlled environmental conditions include lighting, watering and waste management systems, harnessing renewable energy, sensors of all kinds, and other smart devices to autonomously control and fine-tune environmental parameters. Machine learning and automation are used to optimise growth conditions and manage the installations. For example, the partly EU-funded company Infarm has connected its widespread point-of-sale farms to a central platform that learns from the growth data of each farm, adjusting conditions and optimising growth. The redesign of buildings and innovation in construction materials and techniques also plays a role in shaping vertical farms.

Vertical farms are energy-hungry. Some of the energy-related costs can be offset by savings from not using agri-chemicals, from considerably smaller transport, storage and distribution costs, and from less spoilage and waste. But the current energy crisis could have dire consequences for the sector. Sustainable generation of electricity, improvements in battery storage and in the efficiency of LED lights will be essential for the sustainability and economic viability of vertical farming. The use of energy also has implications for the carbon footprint of the

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vertical farms: whether they are fossil fuel- or renewable-powered makes a significant difference. Shorter distribution chains mean fewer transport emissions, but that does not necessarily imply fewer emissions overall for vertical farming. Therefore, research is ambiguous about whether overall carbon emissions are lower for vertical farming than for traditional farming methods.

The number of vertical farming initiatives in Europe is relatively small. While some focus on selling fresh produce, others offer agriculture-as-a-service or sell model vertical farms. On the global market, estimated at €4 billion, Europe comes behind North America and the Asia-Pacific. The sector is young, capital-intensive, and starting a business comes with a risk. Scaling up vertical farms is not straightforward: what works for some companies or on a small scale, might not be the right model for others.

Vertical farmers will require a high level of specialisation, with farms most likely managed by teams of experts with different backgrounds. These will include mechanical, electrical, agricultural and biological engineers, growth managers, architects, data scientists, software developers and cyber-experts. Moreover, with using autonomous robots to handle harvesting, planting and logistics, vertical farming will requires less traditional agricultural manual labour, bringing fear of job losses. The artificiality of vertical farming may scare consumers that have romanticised images of traditional farming, often kept alive by advertising. However, the hyper-local nature of vertical farming may also reconnect consumers with the food production process and help make some fruits and vegetables more readily available.

Since almost 50 % of the calories we consume come from cereals such as rice and wheat that are not grown vertically, vertical farmers will not feed the world. However, vertical farming proposes solutions to the challenges of modern agriculture while contributing to urban sustainability. With all the advantages and challenges of vertical farming, and indoor farming alternatives such as greenhouses, cost-effectiveness is questionable. However, with further technological development and the confidence and knowledge arising from experience in the industry, the performance of vertical farming is likely to improve while costs fall. Finally, the approach may work particularly well for some crops in some environments, such as urban food deserts and metropolises where land is scarce and expensive, or for farming in extreme environmental conditions, for instance in space.

Anticipatory policy-making

Urban agriculture, including vertical farming, has the potential to contribute to viable food production, sustainable management of natural resources, climate action, and balanced territorial development. In March 2020, the European Commission adopted a new circular economy action plan with food, water and nutrients representing one of the key value chains, and, in May 2020, the farm to fork strategy at the heart of the European Green Deal. Vertical farming could contribute to these objectives by reducing the use of agri-chemicals and water in agriculture, and by countering soil degradation, deforestation and water eutrophication (increased nutrient load).

Vertical farming is included in US federal agricultural policy as of 2018. While the EU has been funding initiatives with a vertical farming-related theme under research programmes, the European Regional Development Fund (ERDF) and the European Agricultural Fund for Rural Development (EAFRD), it is not covered by EU agricultural and climate policies. This could partially be attributed to the nature of vertical faming as a policy theme, as it is found at the intersection of rural and urban planning, and research and development (R&D) and agricultural policies. To make vertical farming a successful contributor to the food supply, it will have to be recognised in public policy. R&D efforts could focus on reducing operational costs and the high energy demand, as well as addressing challenges related to economic profitability and consumer acceptance. Financial incentives from governments should also make vertical faming feasible for small producers, not just big tech.

Under the EU rules currently in force, vertical farming is not considered as organic farming. A special certification system may be needed, as well as establishing standards for vertical farming facilities and practices. Similarly, vertical farming managers and workers will need certified, and recognised training and education opportunities.

Fruit and vegetables grown in vertical food factories might come with premium price tags catering to affluent citizens, leaving those worse off without access to the food grown in their neighbourhoods. Lastly, similar to many other emerging applications, a close watch will have to be kept over the cybersecurity issues related to smart farming.