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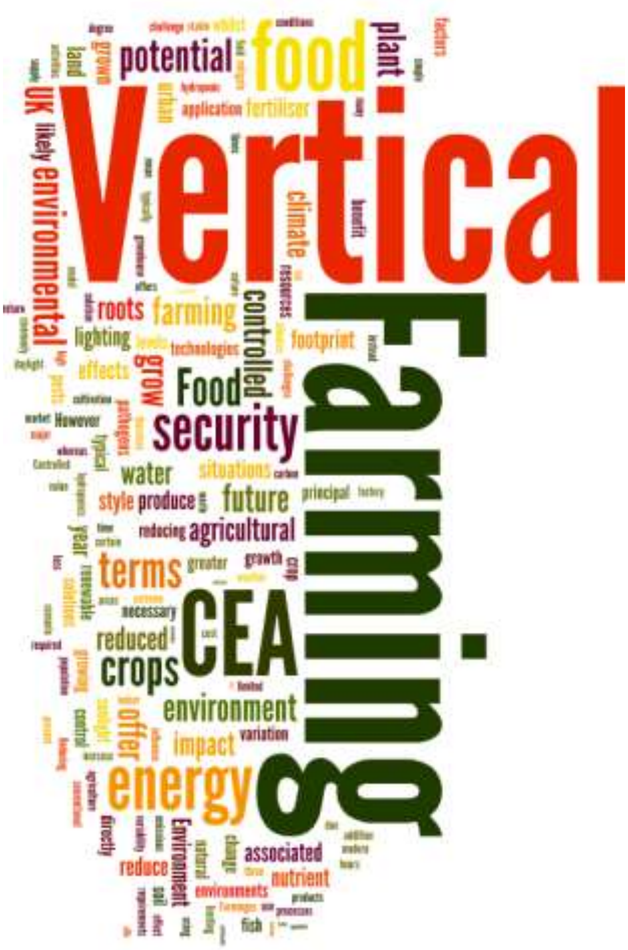
Vertical Farming: A new future for food production?

Dr William Stiles & Dr Peter Wootton-Beard: IBERS, Aberystwyth University.

Take home messages:

- Vertical farming is a system of food production in controlled, indoor environments
- This allows factory style precision agriculture
- This approach can reduce the environmental impact and the influence of environmental variability associated with future climate change on food production.

Controlled environment agriculture (CEA), more commonly known as Vertical Farming, is the process of growing food or other agricultural products within factory-style situations, without the typical natural resources associated with plant production, such as soil and sunlight. These resources are instead provided via the use of innovative lighting and nutrient delivery technologies.



Vertical farming is most commonly associated with urban farm production systems, as these can easily be integrated into urban landscapes, reducing the length of supply chains. However, this style of production may also have the potential to benefit general agricultural production outside of urban situations. Using controlled environments, crops can be cultivated which may otherwise be unsuited to UK climates, reducing reliance on overseas supply chains.

Food production systems also face numerous future challenges with regard to [feeding growing populations](). Vertical Farming allows

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for faster, more controlled production, irrespective of season. One acre of vertical farming can provide the produce equivalent to between 10-20 acres of conventional production. This system offers a model to enable greater future food security, as production through such controlled systems is not vulnerable to variability of factors such as climate or pests and pathogens. Furthermore, a vertical farm can take advantage of low value land otherwise unavailable for food production. Vertical Farming is thus regarded as a realistic future farming system, which may offer the stable model needed for future food production, to provide for the 3 billion increase in population predicted by 2050.

Current systems

There are three main systems utilised for CEA: hydroponics, aeroponics and aquaponics. All three are systems for the growth of vegetation using no soil, but instead nutrient rich water solutions, which plant roots access directly.

In hydroponic systems, the nutrient solution is pumped around reservoirs which the plant roots grow directly into, whereas in aeroponic systems, the plant roots grow free and a water and nutrient solution is sprayed directly onto them. This increases the degree of aeration of the roots, which can have favourable effects in terms of plant health and growth potential. Aquaponics is a combination of aquaculture and hydroponics. Linking these systems means that the plants can use the fish waste as a fertiliser. Meanwhile, the hydroponic system filters the water before returning it to the fish. This can be an effective production system when crop/fish pairings requiring similar environmental conditions are chosen, as it reduces the cost burden for fertiliser and produces an additional crop in the form of fish.

Environmental Impact

Reducing the environmental impact of modern farming is important to achieve sustainability. Vertical Farming systems can offer a raft of potential opportunities to reduce environmental impact. This approach offers a system with no loss of nutrients to the environment, vastly reduced land requirement (10-20 times), better control of waste, less production loss to pests and diseases (~ 40% less), year round crop production, increased daylight hours or growing time per day, no variation in productivity due to weather variation, and no adverse effects of extreme weather events. Most vertical farms also use 70-80% less water than conventional growing. Globally, around 70% of the fresh water available for human use is used for agriculture, which is a major environmental and human health issue. In the UK, this figure is much lower (~10%); but this is likely to increase as a consequence of climate change.

A CE system can present a scenario where, in principal, all production factors can be regulated. The precise nature of this approach means that the use of expensive materials such as fertiliser can be targeted and limited to only what is necessary. This system therefore avoids costly and damaging losses to the environment. As a simple consequence of regulating all the inputs to plants, the potential for inadvertent contamination is also reduced. In typical field environments, heavy metals or pathogens can contaminate soils, both inadvertently through the application of soil treatments and fertiliser, or via natural processes. High levels of control therefore reduce the interaction between crops and pests or pathogens, increasing food security and safety. In extreme instances, should bio-security measures fail and disease outbreaks occur, then production can be resumed in the short term, whereas in typical agriculture the same effect is likely to mean a lost year.

Using life cycle analysis (LCA) it has been possible to assess the carbon footprint of food grown through CEA. This analysis shows that at the moment more carbon is emitted as a result of CEA production than conventional techniques. This effect may be offset by the application of renewable energy sources. The use of renewable energy could reduce the carbon footprint enough to equal or exceed conventional production. In addition, intensifying production in controlled situations such as this, which require a relatively small footprint in land terms, allows more land to be set aside for natural processes and ecosystem service provision. It has even been suggested that the land freed from agricultural production because of this approach, could be returned to hardwood forestry, which could actively mitigate against the effects of climate change.

Energy efficiency

The principal limiting factor for a CE system is the amount of energy required to grow produce, and thus the economic cost of production. This fact has drawn criticism from several areas with regard viability, and to whether CEA has merit in terms of reducing environmental impact and delivering food security solutions. However, modern renewable energy technologies may hold great potential in terms of converting sunlight and wind power into usable energy for internal heating and lighting. In addition, low energy lighting systems, such as those utilising LED bulbs, may limit the level to which energy is required. A study that modelled energy requirements indicated that solar panels could produce sufficient energy to meet lighting and water pumping requirements, suggesting a good degree of feasibility in production terms with the application of renewable energy technologies. Of course, this is likely to only be the case in areas with plentiful sunlight.

Furthermore, vertical farms have yet to be built taking advantage of developments in energy efficient architectural design, (i.e Passivhaus). By growing selected crops, a vertical farmer knows exactly what the internal environment is that they require, and therefore a building can be designed to maintain that environment with the maximum use of energy efficient technologies such as heat recovery, passive ventilation and advanced materials. Food production in controlled environments allows systems to be developed which can capitalise on all opportunities to recapture and re-use resources. This can come in both the recycling of building energy, or the recovery of energy from the non-used plant products, such as roots.

Vertical Farms have basic requirements for heat, energy, CO_2 and nutrients and as such, represent an excellent opportunity for co-location with other systems. Any operation or process that generates a surplus of these resources is an opportunity to improve the economic potential of both that business and a vertical farm. Examples could be on-farm anaerobic digestion, renewable energy production, CHP plants, server farms or industrial food processing plants. This mutually beneficial economic model potentially allows value to be reclaimed from what would otherwise be wasted resources, and which would require further energy to generate anew.

Which crops to grow?

In simple terms, choosing crops which have a rapid growth potential and a high market value is likely to return maximum value. By virtue of not being limited by seasonal variation, crops can grow continuously. Thus, those that can be matured ready for sale in the shortest period of time, offer the greatest benefit in terms of financial return.

It is possible to argue that any crop has the potential for indoor cultivation, yet this is perhaps too simplistic a position to take. By the nature of the activity, CEA allows crops to be grown which may otherwise struggle in the UK climate, either at certain times or throughout the year. By focussing on crops which would only be available through importation, CEA can increase UK food security, reduce the environmental footprint of sizeable supply chain distances, and offer farmers the chance to grow premium crops locally, which would previously have been unfeasible for cultivation in the UK.

Furthermore, no crop as yet has been bred specifically for growth in controlled environments, representing an interesting new challenge for researchers and breeders. The use of artificial lighting can mean individual wavelengths of light can be controlled, which could improve plant growth and nutritional quality. New varieties specifically bred for these conditions (both environmental and physical) will need to be developed, which can fully capitalise on these new opportunities.

Summary

Global food production systems need to address significant challenges in the coming decades. Finding ways to feed a growing global population whilst reducing environmental impact of agricultural activities is of critical importance.

Vertical farming offers a realistic alternative to conventional production for some crops. It could help to achieve the necessary level of food production, whilst overcoming some environmental challenges. This approach may also allow for the production of goods which are highly desirable to UK consumers, but which can only be cultivated in climates warmer than our own.

These systems are at an early stage and more research is necessary to understand its environmental and economic impact. Yet, as we build more, and innovation continues to address the production problems, vertical farming is likely to become more commonplace, in both urban and more rural situations.

September 2017

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