Does it really stack up?

Agriculture: Growing crops in vertical farms in the heart of cities is said to be a greener way to produce food. But the idea is still unproven

WHEN you run out of land in a crowded city, the solution is obvious: build upwards. This simple trick makes it possible to pack huge numbers of homes and offices into a limited space such as Hong Kong, Manhattan or the City of London. Mankind now faces a similar problem on a global scale. The world's population is expected to increase to 9.1 billion by 2050, according to the UN. Feeding all those people will mean increasing food production by 70%, according to the UN's Food and Agriculture Organisation, through a combination of higher crop yields and an expansion of the area under cultivation. But the additional land available for cultivation is unevenly distributed, and much of it is suitable for growing only a few crops. So why not create more agricultural land by building upwards?

Such is the thinking behind vertical farming. The idea is that skyscrapers filled with floor upon floor of orchards and fields, producing crops all year round, will sprout in cities across the world. As well as creating more farmable land out of thin air, this would slash the transport costs and carbon-dioxide emissions associated with moving food over long distances. It would also reduce the spoilage that inevitably occurs along the way, says Dickson Despommier, a professor of public and environmental health at Columbia University in New York who is widely regarded as the progenitor of vertical farming, and whose recently published book, "The Vertical Farm", is a manifesto for the idea. According to the UN's Population Division, by 2050 around 70% of the world's population will be living in urban areas. So it just makes sense, he says, to move farms closer to where everyone will be living.

Better still, says Dr Despommier, the use of pesticides, herbicides and fungicides can be kept to a bare minimum by growing plants indoors in a controlled environment. Soil erosion will not be a problem because the food will be grown hydroponically—in other words, in a solution of minerals dissolved in water. Clever recycling techniques will ensure that only a fraction of the amount of water and nutrients will be needed compared with conventional farming, and there will no problem with agricultural run-off.

A wide variety of designs for vertical farms have been created by architectural firms. (The idea can arguably be traced back as far as the Hanging Gardens of Babylon, built around 600BC.) So far, however, the idea remains firmly on the drawing board. Would it really work?

The necessary technology already exists. The glasshouse industry has more than a century's experience of growing crops indoors in large quantities, says Gene Giacomelli, director of the Controlled Environment Agriculture Centre at the University of Arizona in Tuscon. It is now possible to tailor the temperature, humidity, lighting, airflow and nutrient conditions to get the best productivity out of plants year round, anywhere in the world, he says. The technology of hydroponics allows almost any kind of plant to be grown in nutrient-rich water, from root crops like radishes and potatoes to fruit such as melons and even cereals like maize.

There are a number of ways to do it, but essentially hydroponics involves suspending plants in a medium—such as gravel, wool or a form of volcanic glass known as perlite—while the roots are immersed in a solution of nutrient-rich water. A constant flow of air keeps the plants bathed in carbon dioxide. Any nutrients and water that are not taken up by the roots can be recycled, rather than being lost into the soil. "You can grow anything with hydroponics," says Dr Giacomelli.

He and his colleagues have created the South Pole Food Growth Chamber, which has been in operation since 2004. This semi-automated hydroponic facility in Antarctica is used to provide each of the 65 staff of the Amundsen-Scott South Pole Station with at least one fresh salad a day during the winter months, when supply flights to the station are extremely limited. The chamber has a floor area of 22 square

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metres and produces a wide range of fruit and vegetables with little more than the occasional topping up of water and nutrients. It does, however, require artificial lighting because the station is without natural daylight for most of the winter.

Let there be light

And that highlights a big potential stumbling-block for vertical farming. In the Antarctic the need to provide artificial light is a small price to pay for fresh food, given the cost of importing it. But elsewhere the cost of powering artificial lights will make indoor farming prohibitively expensive. Even though crops growing in a glass skyscraper will get some natural sunlight during the day, it won't be enough. Without artificial lighting the result will be an uneven crop, as the plants closest to the windows are exposed to more sunlight and grow more quickly, says Peter Head, global leader of planning and sustainable development at Arup, a British engineering firm. "Light has to be very tightly controlled to get uniform production of very high-quality food," he says.

Indeed, even in today's single-storey glasshouses, artificial lighting is needed to enable year-round production. Thanet Earth, a 90-hectare facility which opened in Kent in 2008 and is the largest such site in Britain—it provides 15% of the British salad crop—requires its own mini power-station to provide its plants with light for 15 hours a day during the winter months. This rather undermines the notion that vertical farming will save energy and cut carbon emissions, notes Mr Head, who has carried out several studies of the idea. Vertical farming will need cheap, renewable energy if it is to work, he says.

Some researchers, such as Ted Caplow, an environmental engineer and founder of New York Sun Works, a non-profit group, argue that even using renewable energy the numbers do not add up. Between 2006 and 2009 Dr Caplow and his colleagues operated the Science Barge, a floating hydroponic greenhouse moored in Manhattan (it has since moved to Yonkers). "It was to investigate what we could do to grow food in the heart of the city with minimal resource-consumption and maximum resource-efficiency," says Dr Caplow.

The barge used one-tenth as much water as a comparable field farm. There was no agricultural run-off, and chemical pesticides were replaced with natural predators such as ladybirds. Operating all year round, the barge could grow 20 times more than could have been produced by a field of the same size, says Dr Caplow.

Solar panels and wind turbines on the barge meant that it could produce food with near-zero net carbon emissions. But the greenhouses on the barge were only one storey high, so there was not much need for artificial lighting. As soon as you start trying to stack greenhouses on top of each other you run into problems, says Dr Caplow. Based on his experience with the Science Barge, he has devised a rule of thumb: generating enough electricity using solar panels requires an area about 20 times larger than the area being illuminated. For a skyscraper-sized hydroponic farm, that is clearly impractical. Vertical farming will work only if it makes use of natural light, Dr Caplow concludes.

Vertical, but only three metres tall

One idea, developed by Valcent, a vertical-farming firm based in Texas, Vancouver and Cornwall, is to use vertically stacked hydroponic trays that move on rails, to ensure that all plants get an even amount of sunlight. The company already has a 100-square-metre working prototype at Paignton Zoo in Devon, producing rapid-cycle leaf vegetable crops, such as lettuce, for the zoo's animals. The VerticCrop system (pictured) ensures an even distribution of light and air flow, says Dan Caiger-Smith of Valcent. Using energy equivalent to running a desktop computer for ten hours a day it can produce 500,000 lettuces a year, he says. Growing the same crop in fields would require seven times more energy and up to 20 times more land and water.

But VertiCrop uses multiple layers of stacked trays that operate within a single-storey greenhouse, where natural light enters from above, as well as from the sides. So although this boosts productivity, it doesn't help with multi-storey vertical farms. Even if each floor rotates its crops past the windows so that all plants receive an equal amount of natural light, overall they would get less light, and so produce less biomass, says Dr Caplow. He prefers the idea of the "vertically integrated greenhouse". This idea involves the integration of vertical farms into buildings and offices, with plants growing around the edges of the building, sandwiched between two glass layers and rotating on a conveyor. Shrouding buildings with plants solves the natural-light problem for agriculture, acts as a passive form of climate control for the buildings and makes for a nice view. But the area available is much smaller.

The immediate opportunity may simply be to take advantage of the space available on urban rooftops, says Mr Head, and to pursue urban farming rather than vertical farming. BrightFarms Systems, a commercial offshoot of NYSW, is working with Gotham Greens, another company to emerge from the Science Barge, to create the world's first commercial urban hydroponic farm in Brooklyn. When it opens in 2011, the 15,000 square-foot rooftop facility will produce 30 tonnes of vegetables a year which will be sold in local stores under the Gotham Greens brand name.

Although this is urban hydroponics, not vertical farming, it is a step in the right direction, says Mr Head. "I wouldn't be at all surprised if we saw large retailers with greenhouses on their roofs growing produce for sale in the shop," he says. A few examples of this have already sprung up. BrightFarms, for example, together with a firm called Better Food Solutions, began constructing a large single-storey glasshouse on the roof of a big supermarket in October. The supermarket agrees to buy the produce and owns the farm, while Better Food Solutions builds it and runs it. The first fruit and vegetables are expected to go on sale in early 2011.

It is unclear how competitive this will be. Rooftop farming may not be able to compete with other suppliers in a global market unless people are prepared to pay a premium for fresh, local food, says Mr Head. And it is much less glamorous than the grand vision of crops being produced in soaring green towers of glass. But, for the time being, this more down-to-earth approach is much more realistic than the sci-fi dream of fields in the sky. ■