An alternate method of food production has been proposed—growing large amounts of produce within the confines of high-rise buildings.

The Vertical Farm

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CHRIS JACOBS WWW.UNITEDFUTURE.COM/ROLF MOHR/DEAN FOWLER WWW.MACHINEFILMS.COM (THE VERTICAL FARM PROJECT)

The use of the urban landscape to raise most of our food crops sounds like a waste of valuable city real estate until one analyses the advantages of this radically alternative agricultural strategy: it would greatly reduce our carbon footprint; year-round production of fresh, organically grown fruits and vegetables would be the norm; and the promise of a sustainable lifestyle could be realized, which would include the processing of liquid municipal waste, making it possible to eat nutritiously at affordable costs.

As of January 2006, approximately 800 million hectares (1.94 billion ac) of arable land (this includes grazing land) throughout the world were in use, providing an ample food supply that could feed the majority of the world's population, now in excess of 6.7 billion. This has resulted in a significant loss of biodiversity and disruption of ecosystem functions on a global scale.

To address these problems and those expected to emerge soon, an alternate method of food production has been proposed—growing large amounts of produce within the confines of high-rise buildings. This idea appears to offer a practical, new approach to preventing further encroachment into the already highly altered natural landscape. Known as the Vertical Farm Project, established in 2001, it is an ongoing activity at the Mailman School of Public Health at Columbia University in New York City. Currently, it is in the virtual stages of development, having survived four years of critical thinking in the classroom and worldwide exposure on the Internet to become an accepted notion worthy of consideration at some practical level.

There are a number of reasons why vertical farming might represent a viable solution to global processes as diverse as hunger, population growth, and the restoration of land to ecological functions and services—for example, returning land to natural processes, carbon sequestration, and the like. If vertical farming were to become widely adopted, the following advantages could be realized:

▷ year-round crop production; no crop failures due to droughts, floods, pests, etc.; no use of herbicides, pesticides, or fertilizers;
▷ no agricultural runoff;
▷ farmland would be returned to the natural landscape, restoring ecosystem functions (such as biodiversity) and services (such as air purification);
▷ black- and graywater would be converted into energy (solids are incinerated) and potable water by engineering water collection through evapotranspiration;
▷ energy would be restored to the grid by incinerating nonedible parts of plants and animals;
▷ the use of fossil fuel would be markedly reduced (no tractors, plows, shipping);
▷ abandoned urban properties could be converted into food production centers;
▷ sustainable environments would be created for urban centers; and
▷ vertical farming could be used for the large-scale production of sugar (sucrose) to be used to produce nonpolluting gasoline.

Indoor farming (e.g., hydroponics and aeroponics) has existed for some time. Strawberries, tomatoes, peppers, cucumbers, herbs, and spices grown by these methods have made their way to the world's markets in quantity over the last five to ten years. Most of these operations are small when compared to factory farms, but unlike their outdoor counterparts, they produce crops year-round. Japan, Scandinavia, New Zealand, the United States, and Canada have thriving greenhouse industries, but none, to date, have been configured as multistory entities.

Such a proposal differs radically from what currently exists; it would scale up the scope of operations in which a wide variety of produce is harvested in quantities great enough to sustain even the largest of cities without the need to rely significantly on resources

If vertical farming were to become widely adopted, some resulting advantages would be year-round crop production; no crop failures due to droughts, floods, pests, etc.; no use of herbicides, pesticides, or fertilizers; and no agricultural runoff.

CHRIS JACOBS WWW.UNITEDFUTURE.COM/JAMES NELMS WWW.STORYBOARDSONLINE.COM beyond the urban footprint. A single vertical farm with an architectural footprint of one square New York City block and rising just 30 stories—approximately 3 million square feet (270,000 sq m)—could provide enough calories (2,000 calories per day per person) to comfortably accommodate the needs of 50,000 people, mainly by using technologies currently available.

Constructing the ideal vertical farm with a far greater yield per square foot would require additional research in many areas—hydrobiology, material sciences, structural and mechanical engineering, industrial microbiology, plant and animal genetics, architecture and design, public health, waste management, physics, and urban planning, to name but a few. Yet, high-rise, food-producing buildings would only be able to succeed if they were to function by mimicking ecological processes, namely by safely and efficiently recycling everything organic, including "used" water (that is, human and animal waste), turning it back into drinking water. Strong, government-supported economic incentives would also need to be offered to the private sector, as well as to universities and local government, to fully develop the concept.

Ideally, vertical farms should be inexpensive to construct, durable and safe to operate, and independent of economic subsidies and outside support—in short, show a profit at the end of the day. If these conditions can be realized through an ongoing, comprehensive research program, urban agriculture could provide an abundant and varied food supply for the 60 percent of people that will be living in cities by the year 2030.

The second most important reason to consider converting to vertical farming relates to how waste is handled, particularly that which comes from living in urban centers. All solid waste can be recycled—returnable cans, bottles, cardboard packages, etc.—and/or used in energy-generating projects with technologies that are currently in use.

A major source of organic waste comes from the restaurant industry. Methane generation from this single resource could help generate significant amounts of energy, perhaps enough to run vertical farms without the use of electricity from the grid. Agricultural runoff despoils vast amounts of surface and groundwater. Vertical farming offers the possibility of greatly reducing the quantity of this nonpoint source of water pollution. In addition, it could generate methane from municipal waste currently being funneled into water pollution control facilities. The concept of sustainability could be realized if waste is recognized as a valuable commodity so indispensable to the operation of a farm that to discard anything would be analogous to siphoning off a gallon's worth of gasoline from the family car and setting it on fire.

Vertical farms could be engineered to take in black- or graywater, depending on which is available, and restore it to almost drinking-water quality using bioremediation and other technologies yet to be perfected. Fast-growing

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inedible plant species (e.g., cattail, duckweed, sawgrass, Spartina spp.), often referred to collectively as a living machine, would be used to help remediate contaminated water. They would be periodically harvested for methane generation employing state-of-the-art composting methods, yielding energy to help run the facility. Byproducts from burning methane—CO_2, heat, and water—can be returned to the atmosphere of the vertical farm to aid in fostering optimal plant growth. The resulting purified water can be used to grow edible plant species. Ultimately, any water source that emerges from the vertical farm should be drinkable, and thus completely recycled back into the community that brought it to the farm to begin with. Harvesting water generated from evapotranspiration is seen to have some virtue in this regard, since the entire farm would be enclosed. A cold brine pipe system could be engineered to aid in the condensation and harvesting of moisture released by plants. Nonetheless, several varieties of new technology would be needed before sewage could be handled routinely and safely within the confines of the farm. Lessons learned from the nuclear power plant industry could be helpful in this area.

Vertical farming obviates all external natural processes as confounding elements in the production of food. Growing food within urban centers would lower or even eliminate the consumption of fossil fuels needed to deliver them to the consumer, and would eliminate the need for burning fossil fuels during the act of farming.

So, where would the energy come from that is needed to run the vertical farm? Ideally, full advantage would be taken of technologies centered around methane digestion of the inedible portions of what is grown (i.e., biogas production). Solar, wind, and tidal power could also help reduce dependence on fossil fuels. Iceland and other geologically active regions—for example, Italy and New Zealand—would have a distinct advantage in harnessing geothermal energy, which they have in abundant supply.

Solar and wind could be used to help power the vertical farms and reduce dependence on fossil fuels.

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Converting most food production to vertical farming holds the promise of restoring ecosystem services and functions. It is possible that many of the world's endangered terrestrial ecosystems would come close to a full recovery simply by allowing them to cease being farmland and become natural land once again.

If vertical farming were to succeed, it would establish the validity of sustainability, irrespective of location or life form. Vertical farms could become important learning centers for future generations of city dwellers, demonstrating the intimate connectedness to the rest of the world by mimicking the nutrient cycles that can take place once again when land has been returned to its natural environment.

Hydroponic and aeroponic technology has increased crop yield potential by more than 23 times while decreasing water usage by well over 30 times; LEDs (light-emitting diodes, like those used in many traffic lights) and sulfer-mircrowave lamps are being employed as alternative light sources in certain agricultural environments. These crops grow and are harvested within biomass production systems and plant research units by the Bioregenerative Life Support Project at Dynamac, Inc., at NASA's Kennedy Space Center in Cape Canaveral, Florida. These are constantly regulated, environmentally maintained, hermetically controlled, and completely sustainable agricultural solutions already in existence today.

Nourishing vertical farms within the intolerably impoverished regions of the world's largest urban settings—such as Ethiopia, India, the Central African Republic, and the Gaza Strip—is also a possibility. Taking such ideas from outer space and deploying these strategies within cities is not only feasible, it could also be one of the best ways to take on the agricultural challenges of today and in the near future. **UL**

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[This article is excerpted and adapted from a paper first published in the *Proceedings of the CTBUH 8th World Congress, Dubai, UAE*, "Tall & Green: Typology for a Sustainable Urban Future," March 3–5, 2008.]