OPPORTUNITIES IN CONTROLLED ENVIRONMENT AGRICULTURE

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OPPORTUNITES IN CEA

When you hear the term "hydroponic," do you first think of basement marijuana growers or boutique microgreens destined to garnish a cafe's offering of avocado toast?

Instead, what you should be thinking of is feeding the planet and conserving natural resources.

We face a number of challenges as an increasingly global and complex food system struggles to feed an ever-growing population with an ever-growing appetite for more resource-intensive food. This increased demand is spurred by both population growth and rising incomes, with the majority of that growth in demand occurring in South Asia and Africa.

Meanwhile, one-third of arable land has become unproductive around the world due to erosion, desertification, salinization, and urbanization. Climate change adds additional challenges, and neither the expected increases in crop productivity, nor the expansion of agriculture into marginal lands, come close to the increase in food production that will soon be needed. This is why food grown without soil should be seen as a critical contributor to food security, expanding our agricultural production beyond the limits of diminishing arable land.

This is where hydroponics – and related technologies – come in.

Red Acres Farm's hydroponic operation in Worton, Maryland. Photo from Jenna Riemenschneider.

HYDROPONICS is the growing method in which plants are grown in nutrient enriched water rather than soil. Roots can either be exposed continuously to flowing water or grown in an inert medium through an ebb and flow method.

AEROPONICS is similar to hydroponics, but plant roots are sprayed with the nutrient enriched water rather than submerged.

AQUAPONICS is the combination of hydroponics and aquaculture to create a symbiotic ecosystem. Closed aquaculture systems produce harmful ammonia, but in aquaponics naturally occurring bacteria convert the ammonia to nitrites and nitrates to feed the plants.

PRUNING PRECONCEPTIONS

Controlled Environment Agriculture (CEA), which encompasses technologies such as hydroponic, aeroponic, and aquaponic growing systems, has its share of detractors. Some dismiss it based on popular preconceptions of its niche applications or only associate it with urban agriculture. Other critics run the gamut from skeptical to openly hostile to the concept of CEA, mostly over well-intended concern about issues like energy usage, nutrition, and affordability. Some of these critics also hold a fundamental belief that food should be grown in soil – that's the way it has always been, and thus should always be. Period.

In part because of these preconceptions, CEA has not been part of the mainstream conversation about food security, economic growth, and rural development. Opportunities in the sector are unexplored by researchers, policymakers, or even critics who may otherwise laud the potential environmental benefits of CEA.

So let's "dig deeper" into this soil-free technology and help the public, policymakers, investors – and yes, even critics – see that CEA has grown beyond a niche technology and is now a real option for increasing food security while protecting the environment.

To be clear, CEA production is not a silver bullet that will single handedly achieve food security or sustainable agriculture, but it can and should be a part of a diversified agriculture system that provides nutritious and sustainable food. If researchers, policymakers, and investors can develop a better understanding of the role that CEA can have in a smart and sustainable agricultural system, our global food system will be better off for it.

BUDDING INTEREST

In recent years, interest in CEA has been on the rise. In 2017 alone, hundreds of millions of dollars were invested in high-tech CEA facilities such as AeroFarms, Bowery Farms, and Plenty.

It's estimated that the global hydroponics market will be worth more than $27 billion by 2020. Because of the huge market opportunity, a number of investment groups have entered the sector. These investment groups represent both traditional agriculture funders and investment groups that are typically associated with Silicone Valley tech firms. AgFunder reports that in 2017 alone, $652 million was invested in novel farming systems, with the largest portion of that being CEA, with an increase of 233 percent over 2016.

High-profile investors like Jeff Bezos and Kimbal Musk (brother to Elon), along with well-established firms like Goldman Sachs and Prudential, have made large-scale investments in the CEA sector. However small to mid-size CEA businesses aren't attractive to these large scale investments, and are often ignored by the traditional farm credit institutions; our survey of 71 Farm Credit websites found only three which mentioned hydroponics, indoor agriculture, vertical farming, or novel farming systems.

Eric Archambeau of Astanor, a European agtech venture capital firm, and Kathleen Merrigan of the GW Food Institute visiting Aerofarms with Marc Oshima, Aerofarms Chief Marketing Officer. Photo from Marc Oshima.

Even with the rise in funding for large-scale CEA projects, access to capital is reported as the greatest challenge for CEA producers. The business model of CEA, which relies on large upfront capital investments, can present challenges in obtaining funding from farm credit or community banks and other sources. With only a handful of universities pursuing research related to CEA for food production, the information available to investors is limited. Family foundations, venture capital firms, farm credit banks, crowdfunding platforms, and government agencies are thus left to make decisions based on imperfect information, which increases investment risk.

Despite these financing challenges, it's clear that there's money to be made in this blossoming industry, especially as its benefits become more readily apparent and desperately needed.

THE DIRT

The ongoing debate about CEA within the food and agriculture community hit its peak after a decision by the National Organic Standards Board (NOSB) in November 2017 to allow hydroponically grown food to be certified as USDA Organic. This decision highlighted divisions between those who believe that organic food must be grown in soil, and those who see hydroponics and soil-based farming as complementary systems.

Critics of the NOSB decision, mainly from the Organic Trade Association, National Organic Coalition, Cornucopia Institute, and the Keep The Soil In Organic organization, expressed their disagreement with the decision, stressing that from their perspective, soil is an essential part of organic growing. It is important to note, however, that when the Organic Foods Production Act was passed in 1990, the accompanying Senate report stated the expectation of organic hydroponic standards.

Most soil-grown advocates argue that this is not just a reflexive opposition to change, and that soil makes a real difference. And while the debate started within the confines of the USDA Organic label, the effect has been to cast a shadow on all CEA grown produce, with many consumers wondering if there is a nutritional gap between soil grown food and soilless grown food.

For example, farmer Eliot Coleman wrote in an op-ed in Civil Eats that "fertile soil is the most important factor in organic growing because of all its known and yet to be discovered benefits on the nutritional quality of crops. Hydroponic growing removes the crucial soil factor and replaces it with soluble nutrient solutions that can in no way duplicate the complex benefits of soil."

Other critics, such as Sarah Pope, who blogs as The Healthy Home Economist and whose work has been featured in The New York Times and USA Today, claims that "organic hydroponic produce produces big, watery fruit that is very low in mineral content. In a nutshell, organic hydroponics is not nutrient dense food and is basically a waste of money!"

But are these beliefs grounded in science? In short, no.

Studies have proven that hydroponically grown produce is just as nutritious as soil grown produce. In a review of the scientific literature regarding nutritional quality of CEA produce by the Humboldt University of Berlin, researchers found no difference in quality between produce grown in CEA and produce grown in soil. Another study conducted by Drew Buchanan, researcher at the University of Nevada, Reno, showed that hydroponically grown lettuce actually contained more Vitamin C than soil-grown varieties.

AN ENVIRONMENTAL PERSPECTIVE

The criticisms of CEA go beyond nutrition and are also concerned with the environmental impacts of using energy to grow food. Many CEA systems rely on LEDs to provide lighting for the produce, and while LEDs are much more energy efficient than incandescent or even CFL bulbs, the energy requirement and carbon footprint must be factored into a lifecycle analysis comparison of different types of food production. Researchers at Arizona State University found that lettuce grown hydroponically used more energy than conventionally grown lettuce but had higher yields in a 2015 study. Still, LEDs have increased in efficiency by nearly 50% in the past decade, and continue to improve. And investments in green grid infrastructure will further reduce the carbon footprint of CEA production. Some CEA operations also use sunlight with no additional lighting, and so do not have the same energy issues.

CEA addresses the environmental concerns of traditional soil based agriculture by growing food without soil, avoiding issues of erosion, runoff, and irrigation. CEA can grow plants with up to 98% less water than soil based agriculture, making it a viable option for water stressed areas.

As mentioned previously, much of the criticism or skepticism of CEA comes from a well-intentioned, and environmentally focused place. In reality, in many cases of hydroponic growing uses land and water more efficiently than conventional farming, while reducing pollution and protecting soil. CEA can become a viable strategy for sustainably feeding the world's growing population, especially if the high energy consumption can be overcome through improved efficiency, taking advantage of natural sunlight where available, and/or using cost-effective renewable energy.

So let's look at a few places where CEA is already being done right and making a difference.

SMALL ISLAND DEVELOPING STATES

Small Island Developing States (SIDS) face unique food production challenges due to their small size, isolation, limited resources, and increased vulnerabilities to the effects of climate change. According to the Food and Agriculture Organization of the United Nations' (FAO) *State of Food Security and Nutrition in SIDS*, "food imports, as opposed to national food production, are by far the largest source of food." What is most alarming though, is the trend towards an increasing dependence on imported food. Every Caribbean SIDS is more dependent on imports today than in 1995 and half of Caribbean SIDS import more than 80 percent of their food.

St. Kitts and Nevis is one of the Caribbean SIDS that imports the vast majority of its food. St. Kitts and Nevis is a twin-island nation with a population of about 54,000. In addition to the permanent population, the islands see over 120,000 overnight tourists and approximately 1 million cruise ship tourists annually. The dependence on food imports, however, means that the islands are not maximizing the economic benefits associated with a booming tourist industry. To combat this, FAO suggests that "efforts would need to focus on the supply of fresh fruits and vegetables…by domestic producers." With

Kittitian Harvest before and after breaking down the farm in preparation for Hurricane Irma. Photos from Kittitian Harvest.

arable land at half of what it was in 1961, the islands need an alternative growing method to increase domestic production of fresh produce.

Enter CEA and Kittitian Harvest. Kittitian Harvest is a hydroponic shade house operation on the main island of St. Kitts. Co-founder Keane Mayer decided "St. Kitts and Nevis really needed a different approach to agriculture" and has been growing fruits and vegetables hydroponically there since 2015. Kittitian Harvest is a great example of how the benefits of CEA can be applied outside of markets in urban settings. The operation only needs a shade house in the tropical climate and can easily be deconstructed when extreme weather events occur. In September 2017, when Hurricane Irma ravaged the Caribbean, Mayer was able to take down his shade house and hydroponic piping to prevent damage to the farm and allow him to be up and running shortly after the storm passed. Compare this to the $2 billion in agricultural devastation that Hurricane Maria brought to Puerto Rico just weeks later. While no single CEA farm would be able to support an island state or nation in crisis, the resilience that such a system offers cannot be understated as extreme weather events become more frequent and severe.

The problem remains funding. Investment in small to mid-size farming operations, especially in SIDS, is low and investment in alternative farming methods is no different. Mayer says, "Most private investment is going into farms providing specialty products in high margin markets and that investment isn't getting to places like St. Kitts and Nevis where it can be profitable, albeit less glamorous." But since when does agriculture need to be glamorous to be worth investing in? Mayer doesn't think it should be and when describing the benefits of CEA on the islands he keeps it simple: he can grow more per square foot, with shorter growing cycles, using less water, and efficient labor all while maintaining reasonable returns.

THE CHESAPEAKE BAY

In the Chesapeake Bay, nutrient runoff from agricultural production has had a significant negative impact on the health of the Bay, leading to eutrophication and dead zones. In an attempt to get this pollution under control, the EPA in 2010 implemented a Total Maximum Daily Load (TMDL) – essentially a "pollution diet"– to decrease the amount of phosphorus, nitrogen, and sediment flowing into the Bay's waters. This included all farms in the watershed area, which must have nutrient management plans that document their applications of fertilizers and treatment of runoff.

Here, hydroponic growing has an obvious advantage, as its closed-loop system of water management results in virtually no runoff. Farms that use hydroponic methods are therefore able to produce food without contributing to the erosion or nutrient runoff that pollutes the Chesapeake Bay. These negative impacts are so common in traditional soil-based agriculture that this straightforward benefit of CEA can seem too good to be true, as in the case of a farmer we interviewed who had to carefully explain his complete lack of water pollution to an incredulous Nutrient Management Plan auditor. After many phone calls trying to understand where the

excess water went, the farmer finally sent photographs of the greenhouse with its closed loop water system to the auditor.

The Chesapeake Bay region has a long agricultural history, and CEA can contribute to the future of this region by providing economic opportunities for farmers without adding to the pollution of the bay. These principles can be applied in other environmentally sensitive areas, or areas where soil erosion and nutrient runoff are of high concern.

CONFLICT ZONES

Every year the FAO puts out a report on the *State of Food Security and Nutrition in the World*. Unfortunately, there are several alarming takeaways from the most recent 2017 report.

- World hunger is on the rise for the first time in decades, bringing the estimated number of undernourished people to 815 million in 2016.
- Food security worsened in parts of sub-Saharan Africa, South Eastern and Western Asia and was most notable in situations of conflict.
- The last decade has brought an increase in the number of violent conflicts around the world and most impacted countries already face food insecurity.
- Conflict drives population displacement, and displaced populations are especially vulnerable to high levels of food insecurity and undernutrition.

International efforts to address these issues of food security, conflict, and displaced persons have begun to see CEA as a source of relief. In 2016, the World Food Program (WFP) set up a pilot hydroponics project in the Algerian desert where Sahrawi refugees have lived in camps for over 40 years. Livestock is one of the main sources of livelihoods for the estimated 90,000 refugees, but the desert setting makes it impossible to grow fodder for the animals. Families who can't afford to pay for dry fodder resort to feeding their sheep and goats leftovers, trash, and plastics, often resulting in death of the baby animals and poor quality milk and meat from adults. The hydroponic solution came in the form of solar-powered containers where fodder is grown in seven-day cycles. The WFP trains refugee families or young entrepreneurial cooperative groups to own and run the container units as well as to sell their harvests. The WFP has plans to introduce new crops like alfalfa, vegetables and moringa in the future and is also piloting hydroponic operations in Peru and Jordan.

Sahrawi refugees embracing hydroponics in the desert. Photo from WFP/Nina Schroeder.

Other international organizations like the World Bank and the Norwegian Refugee Council are examining and piloting CEA in conflict zones and conflict adjacent regions where it not only provides additional food security, but also helps vulnerable populations develop productive skills to contribute to their livelihoods.

DIVERSIFIED FARMING OPERATIONS

Many of the headlines about CEA focus on large scale hydroponic start-ups (i.e. Plenty, Aerofarms etc.) where the executives and funders come from a technology or business background. Less attention has been paid to farmers who have chosen to expand their existing farming operations to include CEA as a part of their portfolio.

"INNOVATIVE TECHNOLOGIES SUCH AS HYDROPONICS OFFER HOPE TO THE SAHRAWI REFUGEE COMMUNITY, WHICH IS GRAPPLING WITH THE DUAL CHALLENGE OF CLIMATE CONDITIONS AND FOOD SECURITY."

-From *Growing Food in the Algerian Desert*, WFP Insight 2/28/17

One farm that did just that is Red Acres in Worton, Maryland. A fifth generation family farm, Red Acres has gone through many changes, from dairy farm to hay farm to barley, and now, to lettuce. Bryan Williams, owner, made the decision to add a hydroponic operation in a double bay greenhouse to his 200 acre farm in the summer of 2015 when his hay allergy finally made him consider changing his operation. After many years of difficulty breathing while farming, he learned about hydroponics, and got in touch with CropKing, a vendor which supplies hydroponic equipment. Williams built the greenhouses over the course of two months, and had much to learn about both the growing system and the market for locally grown greens.

Today Red Acres produces eleven varieties of greens in over 9,000 growing slots. Williams sells to a number of small family owned grocery stores and has a small store on his farm for visitors as well. He still farms his 200 acres with hay, straw, corn, barley, wheat, and soy, but he estimates that about half of his revenue is coming from the greenhouses which take up less than a fifth of an acre of land.

Red Acres Farm's hydroponic operation represents just a small portion of the farm's footprint, but half of its revenue. Photos from Ariel Kagan.

STRATEGIC USE OF SOIL

A lot of our challenges are clear. Arable land is decreasing globally due to soil erosion, urbanization, desertification, salinization, and climate change. Our global population continues to increase, as do our appetites for not-always-sustainable diets. We're also increasingly disconnected from our food systems.

We have to grow smarter. Producing food without arable land constraints would provide numerous benefits including increased food production, particularly of fresh and local food; employment opportunities for urban populations, estimated to account for up to 75 percent of the global population by 2050; and the strategic use of soil resources for food production that is most suitable or necessarily must be soil-based.

In the U.S. alone, over a quarter of a million acres of land are planted with lettuce (head, leaf, and romaine). An additional 322,100 acres are dedicated to growing tomatoes. Both of these crops are very well suited for indoor, CEA growing, where yields can be up to ten times higher per square foot. Both are also annual crops, traditionally requiring annual tilling and harvesting, which can cause erosion and topsoil loss. By moving annual crops like lettuce and tomatoes into CEA production, agricultural lands can be dedicated to crops that are best grown in soil.

CEA has real value for our food and agricultural systems, and can be part of the solution to feeding a hungry planet while also protecting the environment. It's a promising technology that deserves to be taken seriously, which means that it's time to update our understanding of hydroponics and similar technologies, and their impacts on resources and nutrition. We encourage further research into the potential of CEA, smart state and federal policies that provide grant and loan programs for CEA producers, and equal access to capital for small holders in this new wave of investment in agtech and innovation.

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ABOUT THE FOOD INSTITUTE

The GW Food Institute is home to faculty and student scholars engaged in research about all things related to food, from sustainable agriculture to the way diet and meals shape human society. Healthy communities depend on sustainable food systems that are resilient, diverse, fair, economically balanced, and transparent. Established in September 2015, the GW Food Institute brings together a wide range of scholars to focus collaboratively on:

- The science and technology of food, health and nutrition
- Policy, law and justice
- The business and economics of providing food
- Food citizenship and leadership
- Food history and culture

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