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# Innovation in natural capital investing: controlled environment agriculture

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*Investment in farmland is driven by two long-term dynamics:*

1. *Population growth increasing demand for agricultural crops and*
2. *A fixed global farmland base*

These factors reduce the amount of arable land-per-person. The current world population of 7.6 billion is expected to reach 9.8 billion in 2050 according to a United Nations estimate. This growing population is anticipated to double the demand for food.[1] Because farmland supply is constrained by a range of factors, including a need to protect shrinking areas of natural ecosystems, land use conversion and climate variability — greater productivity per unit area is needed to meet the expected increase in food demand.

These dynamics put conventional farmland investments in a strong, long-term position. However, as other means of food production, like controlled environment agriculture (CEA) develop and grow, the investment landscape is changing.

Investors may be wondering what CEA strategies encompass and what might be the impact on conventional farmland investment returns?

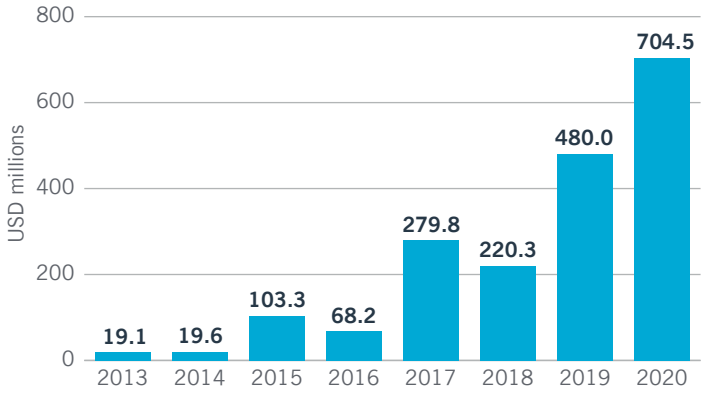
In this paper, we introduce the CEA approach to farming and examine the CEA industry and types of investment strategies that exist in the marketplace. We also evaluate whether CEA and conventional farming can coexist, and what this means for investors in conventional, land-based food production moving forward.

## WHAT IS CEA?

CEA in its simplest form is an enclosed environment, technology-based approach to farming that allows a farmer greater control over production-related variables. Specifically, indoor production allows producers to closely control inputs for an efficient crop output. The complexity of CEA systems varies greatly; the simplest form being low-tech, outdoor tunnels and the most complex including fully automated lighting, water and ventilation.

Investment in CEA has gained momentum due to technological innovation, climate variability impacting crop yields, and rising consumer demand for locally produced food. Figure 1 shows publicly announced CEA investments which have grown 34x since 2013.

### Figure 1: Funding for CEA start-ups has grown




Source: S2G Ventures, Pitchbook, 2020

## CEA TECHNOLOGY: METHODS OF PRODUCTION

CEA encompasses a diverse set of production methods, ranging from the use of very simple to very complex technologies. The degree of technology adoption, input costs, crop mixes, and level of control vary significantly depending on the type of CEA system. CEA can be broken down into five primary production systems. Their level of environmental control — a proxy for the amount of technology involved in the production process — is summarized in Figure 2.

### 1. High tunnels

Crops are grown on raised beds or directly in the ground, and there is little to no automation. The initial capital expenditure and follow-on maintenance are relatively low. From a production environment standpoint, these operations are closest to conventional agriculture. A significant range of crop types (mainly high-value fruit and vegetables) can be grown using high tunnels due to the similarity to conventional agriculture.

### 2. Greenhouses

Using natural lighting to supply a portion of a crop's needs, greenhouses are transparent, enclosed structures made of glass or hard plastic. Greenhouse production can use pots and soil, which, like conventional agriculture, requires deep, well-drained soils and adequate access to good, quality water.

Greenhouses can also implement a soil-less production system using hydroponics. They tend to involve a substantial initial capital investment and use a varying degree of technologies. Depending on the technology implemented, greenhouses can have a very little or very large amount of automation. Greenhouses tend to grow a diverse set of leafy greens and vegetables.

## 3. Vertical Farms

Operate by stacking plants vertically on shelves or tall pillars (e.g., in shipping containers), which can allow for up to 10x the yield of a given land area. Plants are grown in completely enclosed conditions, with LED lights replacing sunshine and a closed-loop system for water and nutrient recycling. Due to the highly mechanized nature of vertical farming operations, there is significant use of automation. Due to the vertical stacking, the crop mixes that can be grown are limited to smaller types of produce such as leafy greens and herbs.

## 4. Container Production

Self-contained growing units that use similar technology to vertical farming, such as hydroponics and artificial lighting. Container production strives for standardization, limiting the crop mix relative to other forms of agricultural production, but it is an ideal growing environment for leafy and micro-greens.

## 5. Aquaponics

This production method combines aquaculture, which is growing fish and other aquatic animals, and hydroponics which is growing plants without soil. Aquaponics uses these two in a symbiotic combination in which plants are fed the aquatic animals' waste. In return, the vegetables clean the water that goes back to the fish. The difference between aquaponics and hydroponics is that it also uses nutrients from fish to grow the plants as opposed to grower-added nutrients. Aquaponics has some automatic controls, but, generally, is not fully automated. Due to the limited nutrients available from the fish themselves, aquaponic operations tend to produce a rather limited crop mix (mostly leafy greens) when compared to greenhouses or high tunnels.

### Figure 2: CEA systems and their level of environmental control

● Full control ◑ Partial control ○ Limited control

| Production environment | Temperature | Water | Nutrients | Light |
|---|---|---|---|---|
| High tunnel | ◑ | ● | ◑ | ○ |
| Greenhouse | ● | ● | ● | ◑ |
| Vertical/ container farm | ● | ● | ● | ● |
| Aquaponics | ● | ○ | ◑ | ◑ |

Source: Nuveen Natural Capital analysis

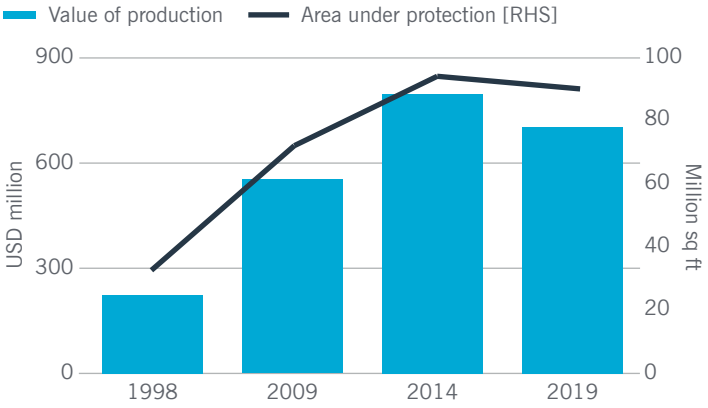
## CEA PRODUCTION AND COSTS

CEA in its various forms has increased in the U.S. and around the world. This is due to the agronomic benefits it enjoys compared to conventional, field-based agriculture:

- Reduction of crop yield volatility
- Highly measured and controlled input use
- Extended or year-round growing season
- Reduction in transportation cost
- Off-season price premiums when supply from conventional sources diminish

Figure 3 shows a significant increase in the value of production and footprint of various CEA systems in the U.S. over the last 20 years. While this increase is notable, the value of production coming from CEA systems is just a fraction of that relative to conventional, field-based production. For example, the value of tomato production in California alone totaled $1.18 billion in 2021, dwarfing CEA production across all regions and crop types.

## Figure 3: U.S. CEA production* by value and area




Source: USDA Census of Horticulture, NNC analysis
*Food crops grown under glass or other protection. Includes crops grown hydroponically.

Europe has also seen a proliferation of CEA production, ranging from low-tech high tunnels to state-of-the-art greenhouses. The Netherlands is a global leader in greenhouse production and technology, with over 26,000 acres of greenhouses producing greens, vegetables and ornamental crops for domestic and export markets. Figure 4 shows the number of vegetable-producing greenhouse businesses has decreased over time; however, the total area of greenhouses has increased 38%. This highlights the importance of economies of scale given the high level of capex and operating costs required when producing food in controlled environments.

Virtually any crop can be grown indoors with the right conditions. Typically, CEA systems produce higher value crops or those that fill a supply gap when the typical outdoor growing season ends.

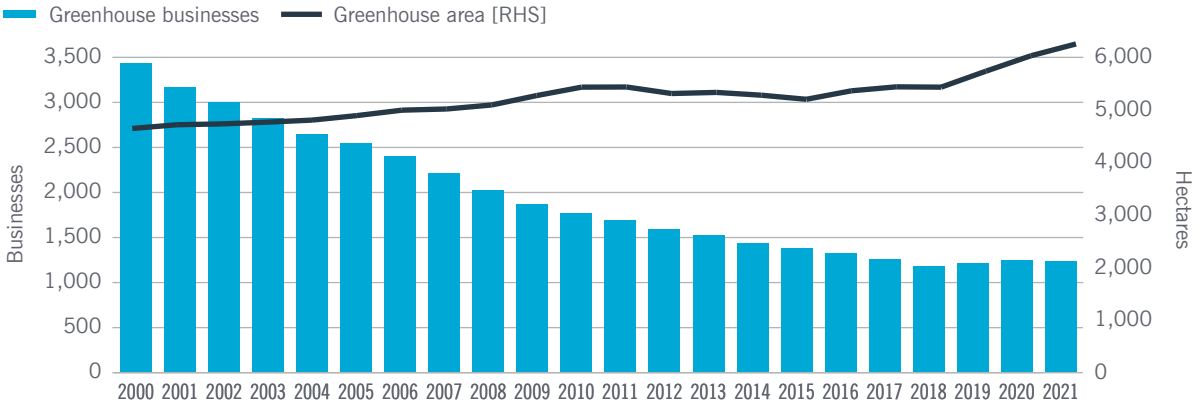
Figure 5 shows tomatoes are the most widely grown crop in controlled environments by value of production. There are clear crop mix differences between vertical and greenhouse farming. While greenhouses can successfully incorporate tomatoes, cucumbers and peppers, vertical farm crop mixes tend to be predominately leafy greens (lettuce, chard, kale) and herbs (basil, mint, chives, and parsley).

The cost to produce crops in high-tech greenhouses or vertical farms varies significantly by system. Cost structures naturally increase as more technology and operational knowledge are required. A CEA project with a moderate degree of technology will need:

- Land (owned or leased) to support the production activities. In the case of vertical farms, land is sought within or adjacent to urban centers to reduce transportation costs, but this strategy can significantly increase the price of land relative to conventional farmland on a per acre basis
- A building or structure
- An irrigation or hydroponic system as well as lighting and ventilation
- Labor with various levels of technical skills
- Energy to run the growing, lighting and ventilation systems

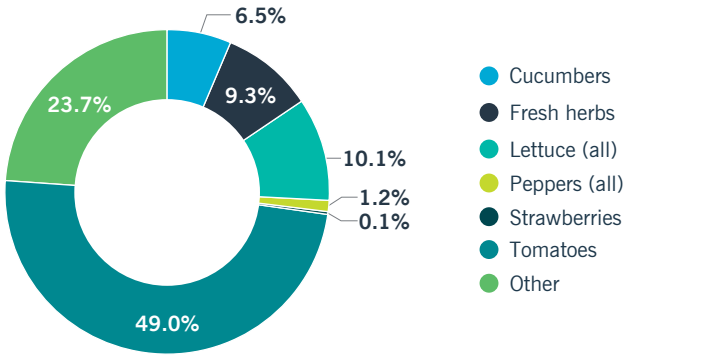
Although most CEA systems produce higher yields per unit area than conventional farming, production costs are much higher than conventional agriculture. A 2019 study[2] by researchers at Cornell University

## Figure 4: Vegetable greenhouses in the Netherlands




Source: Wageningen University & Research

## Figure 5: Breakdown by value of crops grown in CEA systems in the U.S.




Source: USDA Census of Horticulture 2019, NNC analysis

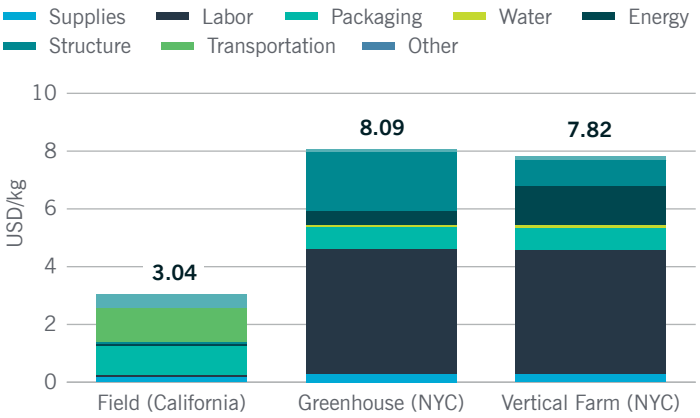
derived the production costs in Figure 6 to grow and deliver a kilogram of leafy greens to a New York City produce market.

The three production methods considered are conventional, field-based agriculture in the Central Valley of California, a high-tech greenhouse and a vertical farm. Both the greenhouse and vertical farm are assumed to be located within the New York City metropolitan area. Their findings show that a local high-tech greenhouse and vertical farm have production and marketing costs that are 166% and 157% higher, respectively, than conventional field-based production in California.

In addition to the overall differences, the cost structure of each is vastly different. For the conventional system, harvesting, packaging and shipping costs account for approximately 70% of costs. For the high-tech greenhouse, structures, electricity, and labor account for 80% of costs.

Given energy use accounts for a greater share of costs in the greenhouse and vertical farm systems, the authors note that kilograms of $CO_2$ equivalent per kilogram of produce is 3% and 110% higher for the greenhouse and vertical farm, respectively, relative to field-based production. Although it is outside the scope of this paper, a detailed analysis is required to determine the environmental trade-offs of each system.

## Figure 6: Cost to produce and deliver one kilogram of leafy greens to a New York City produce market




Source: Cornell University, 2019

## WHAT ARE THE RISK AND RETURN CHARACTERISTICS OF CEA INVESTMENTS, AND HOW DO THEY DIFFER FROM CONVENTIONAL FARMLAND INVESTMENTS?

Given the many production systems within the larger category of CEA, here we focus our comparative analysis of conventional farmland to high-tech vertical farms due to the recent and significant investment into this strategy.

Both conventional farmland and a vertical farming operation involve a large initial capital investment, the latter being comprised of property, plant and equipment, while the former is mostly bare cropland. Farmland investments are generally grouped into two categories: annual and permanent cropland.

- Annual crops, such as corn, soybeans, wheat and fresh vegetables, complete their lifecycle in under a year, allowing farmers to change production year-over-year as profitability or agronomic considerations change. Annual cropland investors generally operate farmland by leasing it to a local tenant
- Permanent crops require an investment in farmland, but also in the biological asset (trees or vines) grown on the property. The useful life of a particular biological asset will vary by crop type, but in general are expected to be economically viable for at least 20 years

In terms of managing a permanent crop investment, a farmland investor can lease it to a third party or operate it directly by outsourcing field operations to a contractor (custom operating).

By directly operating, the farmland owner assumes price and production risk associated with the crop, which has the potential to increase the income returns over a lease strategy.

Institutional farmland portfolios often have a mix of annual and permanent crops, allowing for diversification among crop types and operating strategies. This is a key differentiator when comparing farmland to CEA. To illustrate the differences in conventional farmland and CEA investments, we analyzed key investment variables, such as total return and its constituent parts, and risks associated with each investment.

## Return dynamics

Conventional farmland benefits from total return being generated from both annual income generation (whether leased or operated), as well as capital appreciation of the land values over time. In most cases, conventional farmland is expected to appreciate over time. Population growth will create higher demand for food from an increasingly constrained supply of land. Together, these two factors increase the value of production derived from the land as well as the value of the land itself due to scarcity, which drives appreciation of the asset. Conventional farmland investors may see anywhere from 3% to 6% appreciation per annum in the underlying value of their investment, depending on the portfolio construction and hold period.

Vertical farms require large capital outlays in property, plant, and equipment, most of which are depreciable assets. In addition to the depreciating nature of many CEA investments, evolving technologies could also place a burden on CEA growers. As technological advances continue, systems and initial investments can become outdated relative to new facilities. This can result in the need for additional capital expenditure to remain competitive, or the prospect of becoming less efficient and experiencing margin compression. The land needed to support a vertical farm has potential to appreciate. However, an investor would need to own the land that the building is situated, which is not always the case, as some lease the building space needed to produce crops. A CEA investment is not expected to generate much, if any, capital appreciation; they generate their returns entirely from income.

## Risks

While there are similarities between CEA and conventional farmland investments in that they produce food and are subject to crop price variability, there are different risk considerations. This means these investments should be viewed through different lenses when thinking about allocation or investment strategy.

The considerable capital investment and technical expertise required for vertical farming presents a sizeable risk. This factor along with high operating costs and market development initiatives can create a long timeline to profitability since the total return is predominately generated from annual income.

Given the importance technology plays in the economics of growing the crops and the relative newness of certain CEA operations like vertical farming, this is a risk to both producers and investors. A malfunction or downtime in technology has the potential to cause a total crop loss. In addition, the price of energy can have a material impact on the economics.

Risks related to conventional farmland includes weather, which can impact yields in any given year, and trade policies, which can influence or even disincentivize agricultural trade between countries. These risks can be offset by building a diversified farmland portfolio by country, crop type and operating strategy.

### WHAT DOES THIS MEAN FOR INVESTORS?

Long-term population growth and constrained farmland supply underpins the need for increases in food production and efficiency. A diverse set of agricultural production systems — both conventional and CEA — will be needed to sustain an expanding population and meet growing demand for food. An investment in farmland allows an investor to own an appreciable asset while generating a stable income return. An investor can also diversify their portfolio with vegetables, grains and oilseeds, tree nuts, and fruit-producing properties.

Farmland as an asset provides a good inflation hedge while also having low correlations with the traditional asset classes of stocks and bonds, making it an ideal investment for investors who would like to diversify their portfolio. It is unknown whether the portfolio-level benefits of conventional farmland investments are shared by CEA investment strategies.

Investments in CEA allow investors to gain exposure to new technologies and uniform production, mitigating many of the risks associated with conventional farmland production.

Compared to farmland, CEA investments offer a limited crop mix and require high capital expenditures with total returns centered around income, resulting in a different investment profile. These differences change the investor experience, putting conventional farmland and CEA investments in different categories of an institutional investor portfolio.

Conventional farmland investments are a better fit in a portfolio as an inflation hedge, offering a steady income return, diversification benefits and a high single-digit total return. On the other hand, CEA likely sits in a private equity or infrastructure allocation, with the potential to generate higher returns with higher risks depending on the operation, strategy, technology implemented and geographic location. While both investments offer exposure to food production, total returns are driven by different dynamics, placing them in different portions of a diversified portfolio.

**For more information, please visit our website, nuveen.com/naturalcapital.**

### Endnotes

1 https://www.worldwildlife.org/initiatives/food

2 Nicholson, C.F., K. Harbick, N. M. Mattson and M. I. Gómez. 2019. An Economic and Environmental Comparison of Conventional and Controlled Environment Agriculture (CEA) Supply Chains for Leaf Lettuce to US Cities, in E. Aktas and Michael. Bourlakis (eds.) Food Supply Chains in Cities: Modern Tools for Circularity and Sustainability



### A word on risk

As an asset class, agricultural investments are less developed, more illiquid, and less transparent compared to traditional asset classes. Agricultural investments will be subject to risks generally associated with the ownership of real estate-related assets, including changes in economic conditions, environmental risks, the cost of and ability to obtain insurance, and risks related to leasing of properties.

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