Vertical Farming Economics in 10 Minutes

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Abstract

This paper seeks to provide an in depth understanding of pursuing vertical farming as a business practice in an approximately ten minute read. In this article, I discuss the issues with our current state of agriculture and follow it up with the tangible advantages that might justify a need for vertical farming from a macro perspective. Then I go on to discuss the problems of vertical farming from a business economic perspective, and finally provide a thorough discussion about what the future could hold for this young industry.

The Premise: Why Do We Even Vertical Farm?

Vertical farming is a method of growing plants without using soil or direct sunlight, in a controlled environment in vertically stacked layers, thus the name "vertical farming."[1] The most common products produced by vertical farming systems today are lettuce, tomato, basil, cucumber, and flowers. The products are generally grown in either shipping container environments[2] or large-scale warehouses.[3]

There is no question that vertical farming looks exciting. It is something futuristic looking that does very well to attract our attention. Now, that is a bonus point for any industry, but why do we need it in reality? What is the problem it is trying to solve? There are some important issues with our conventional form of agriculture that might merit some needed innovations in the form of vertical farming. After conducting an extensive literature review, I would categorize the issues in the following segments:

The issues with our current state of agriculture

1. Agriculture accounts for about 70% of our freshwater usage.[4] To understand why this might be a dire issue, we should mention that according to United Nation's 2018 Water Development Report, more than 2 Billion people all around the world lack access to clean drinking water.[5] Moreover, the freshwater sources available to us are being

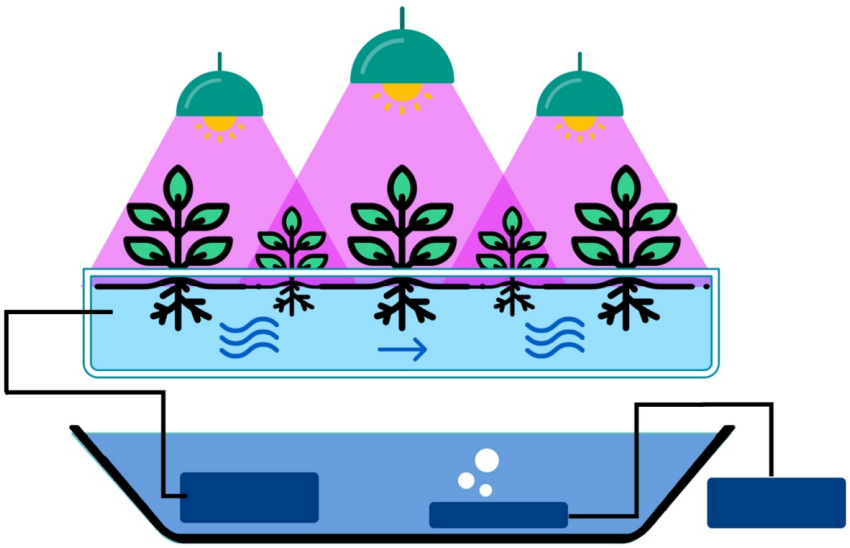
drained faster than they are being refilled.[6,7] So, we have a water problem that might not be going away any time soon, and agriculture is the main consumer.

2. In the past 25 years alone, agriculture has been responsible for wiping out about 1 million square kilometers of forests.[8] To put this in perspective, one can take into account the overall growing population and increasing living standards, both of which tend to increase the demand for more agriculture, and this, in turn, will possibly result in even more land use and deforestation.
3. Conventional Agriculture can be quite risky from some aspects too, as it is heavily reliant on the environmental conditions.
    a. About 30 percent of the produced food is lost to pesticides each year.[9] Also, a farmers' satisfactory production levels are typically a function of favorable weather conditions, among other factors.
    b. Not to mention that pesticides and weather uncertainties, such as climate extremes or changing rain patterns, are only going to get worse due to climate change.

The Promise of Vertical Farming

Vertical Farming could potentially help solve all these problems. Figure 1. illustrates a vertical farming layer where plants are submerged in liquid solutions with added nutrients, subject to UV lights in a control environment setting.

Figure 1. Vertical farming illustrated



1. Vertical farming consumes only 1/10th of the water compared to traditional farming.
2. It does not require fertile land to grow, and it utilizes space radically better, resulting in immensely less cause for deforestation.
3. Moreover, it is not reliant on the environment whatsoever as it is conducted in a closed/controlled environment; thus, no pesticide or weather risks.

The Business Economic Issue!

Well, these advantages are all great. However, vertical farming can also be quite expensive as it is energy and labor intensive. For it to succeed in the marketplace, it must compete with a large scale, highly optimized traditional agriculture. That puts vertical farming's financial prospects in a questionable state at best. Vertical farming has a lot of promise from a macro perspective with regards to the issues we reviewed. However, these advantages can often seem irrelevant from a business economics point of view. After all, even in a more tolerable flashy fundraising/market share culture of today's investments, a business is still expected to eventually make a profit in the competitive marketplace.

The Tradeoff in a Vertical Farming Practice?

To provide a better perspective on the reasons behind the business economic issue, it is important to understand the current technical feasibility and cost efficiency of producing different crops with vertical farming. Theoretically speaking, we can grow any type of crop with vertical farming, ranging from leafy greens and vegetables to grains like wheat and rice. So, the better question to ask is whether it would be desirable to grow a certain product using vertical farming. There are a few important factors dictating the choices to grow particular crops in vertical farming.

The most important influencing factor here is the required energy. Vertical farming basically trades off higher energy consumption to produce faster, with less risk, less water, and better quality, in a smaller space. The important question one should ask about choosing products to grow with vertical farming is whether it would be worth spending that extra energy to gain better quality, higher production efficiency, etc. As of now, the answer to that question is "perhaps under certain conditions" when asked about lettuce and leafy greens, but "absolutely no" when asked about rice and wheat. There are a few reasons for that.

First, lettuce and leafy greens require a relatively small amount of energy or sunlight to grow. They also generally have a high "value to required space" ratio as well, which is due to their relatively low space requirement and high

market value. In addition, if one looks at a produced leafy green, almost all portions of the produced crop are consumable, meaning the production value is a lot more efficient.

On the other hand, commodities like rice are the exact opposite. They require considerably more energy input to grow while taking up a lot of space to produce relatively small consumable portions. Hence, producing commodity crops with vertical farming without some serious innovations in the industry is not realistically feasible. As for vegetables such as tomato or cucumber, they fall somewhere in the middle of this tradeoff spectrum, not as bad as commodity products, and not as appealing as leafy greens. There has been limited production of vegetables like tomatoes recently, but the industry mainly chooses to produce leafy greens at this point, with lettuce being the industry's most dominant produce.

It goes without saying that the promises of vertical farming to help solve the world's water crisis or minimize deforestation are not going to be realized by only producing premium, slightly overpriced lettuce and leafy greens. That said, the future might prove very bright for vertical farming. In the next segment, we will investigate some economic trends that might influence the fortune of the vertical farming industry.

The Future of Vertical Farming

In this section, we seek to gain some perspective into the future of the vertical farming industry. We will look at the two main indicators; vertical farming's profit margin potential and risk aversion potential.

The Profit Margin Potential

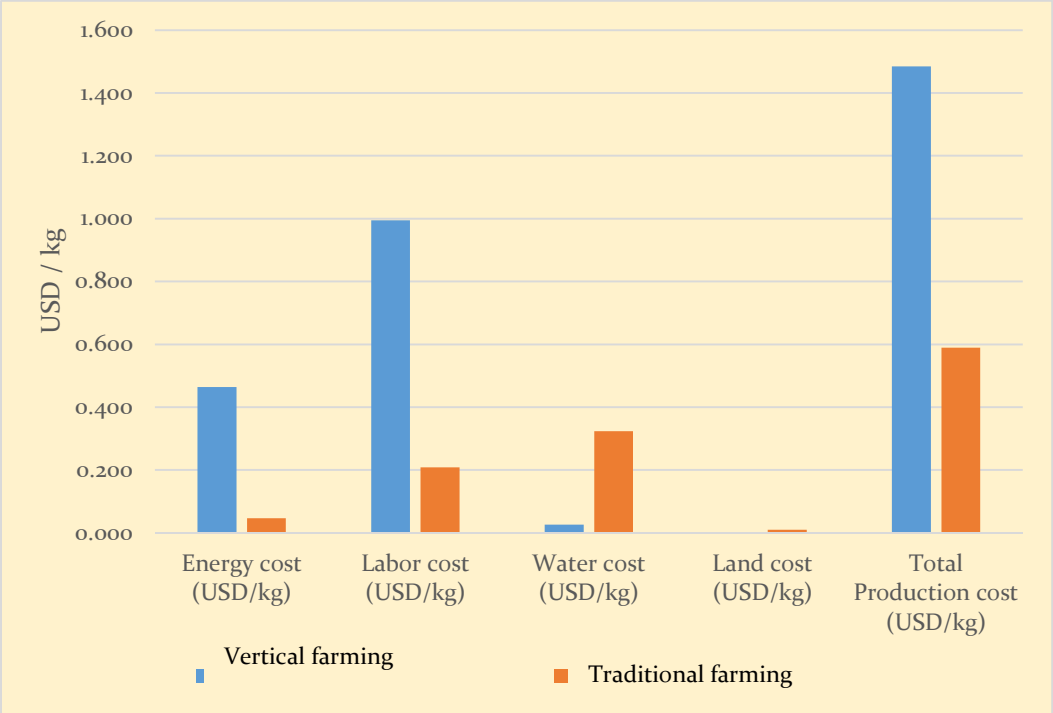
Even with its technological progress, it is commonly known that vertical farming, although it may be able to turn a profit by producing specific crops, is still considerably more expensive than the traditional alternative in most cases.

To gain a better perspective, I have provided the average cost estimations of growing a kg of lettuce in the US with both vertical and traditional farming in Figure 2. These numbers represent an average cost (USD) per kg of production from seven locations in the US for a 90,000 kg yearly production capacity with both practices. A framework similar to the one proposed by Moghimi in 2020 was utilized here and the required data such as labor, regional energy costs, land rates, insurance rates, water rates, local crop prices were plugged in to provide the following estimations.[10-15] This paper shies away from over expanding on the method used to drive the presented estimates here as the material has been described in prior literature and it would distract from the main purpose of this work. However, it should be

noted that the presented estimates are aligned with the findings from prior literature.[16-18]

Figure 2 illustrates the differences in four major costs associated with production in both practices. We should bear in mind that these are average values that are only directed towards forming a better understanding. Obviously, different farming businesses with different technologies and the passing of time will change these numbers.

Figure 2. Average production cost per unit for both farming practices



It can be seen that savings are very slim in land and water costs, where vertical farming holds the advantage. On the other hand, extra spending is considerable in energy and labor costs, where vertical farming is at a disadvantage. We should also have in mind that this gap was only estimated for lettuce production, and it would be a lot bigger if we were discussing other crops such as tomato or rice. Now even by considering a premium quality product state for vertical farming, the industry still has to close this considerable production cost gap somehow if it aims to become the mainstream form of practice. Here, a few factors that might help vertical farming's case in the future are discussed.

Automation: We can see that vertical farming is at a vast disadvantage when it comes to labor costs. But the world is moving towards more

automation, and that might help vertical farming's cost efficiency prospect. We should bear in mind that automation is a double-edged sword between competing industries; in other words, it can occur in both. That said, there is a good argument to assume that vertical farming would be the faster industry to progress technologically as it could have a considerably higher learning rate by having access to the data gathered from its enclosed farming factory and having full control over the environment that the plants are produced in.

Energy Efficiency Technology: Vertical farming currently chooses to pay for electricity instead of using the sun as a free source of energy, and that puts the practice at a huge cost disadvantage. Introducing new technologies that would both reduce vertical farming's energy consumption and provide a way to make use of that free solar energy could help the industry in the future.

Importance of Water: The planet is facing a global water crisis and farming is responsible for using 70% of its freshwater use. Also, water prices have been consistently rising over the past few years.[19] But the water prices, as of now, are still too low to encourage vertical farming's minimal water usage advantage and make a significant difference in the cost of production comparisons. Speculations about the exact pricing of future water rates are better left to economists with expertise in that area. However, there is reasonable evidence to support that water will become more valuable in the future. If that is the case, it would greatly favor the vertical farming practice.

Value of Land: One of the main features of vertical farming is saving space and avoiding deforestation. If fertile land prices happened to increase in the future, whether due to population growth or legislation preventing deforestation, that would heavily favor vertical farming over the traditional practice.

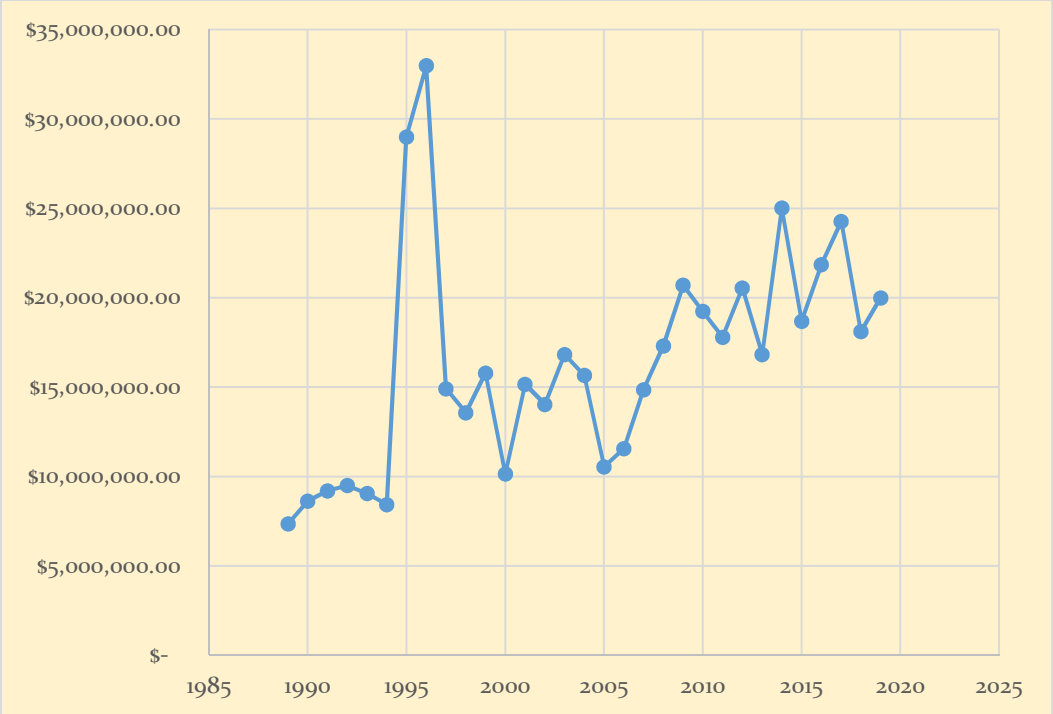
Post-COVID World and the Desire for Local Food: A Post COVID world might have a higher demand for locally grown food, and if that happens to be the case, it could favor vertical farming's prospect, especially if more viable methods are established to grow a greater variety of crops.

The Risk Aversion Potential

One of the main advantages of vertical farming is risk aversion. To potentially utilize that aspect of vertical farming in any country, it is important to understand how farming risk management works in any destination. In the US, for instance, a centralized insurance program has

been established by the federal government, which provides farmers with access to fair price insurance rates with heavily subsidized premiums. This insurance program covers various forms of farming risks ranging from yield insurance that would help underperforming farms in the form of lost salary or production to reimbursing farmers for catastrophe related costs. Obviously, rates and subsidies differ case by case depending on the crop, location, weather data, farm history, etc. But just to gain a better perspective, it is fair to assume a 50%-80% subsidy rate for 50%-80% yield/income insurance. For instance, with the data raw data acquired from USDA's public dataset,[20] Figure 3 shows the yearly subsidies paid with taxpayer dollars for a group of tobacco crops in the past 30 years after adjusting for inflation. This set of crops have had about 58% subsidies on their premiums in recent years on average. We should have in mind that tobacco generally has relatively lower subsidy rates for obvious reasons.

Figure 3. Federal Subsidy ($) for Tobacco Group Crops Over the Years (Inflation Adjusted)*



*The basket includes Tobacco, Burley Tobacco, Cigar Binder Tobacco, Cigar Filler Tobacco, and Cigar Wrapper Tobacco

Now, with this context in mind, due to current low insurance rates and government subsidies in the US, the average insurance paid by a traditional farmer for growing a kg of lettuce could be as low as $0.004 annually. We can

see why this low figure might hinder possible risk aversive incentives with regards to vertical farming when the cost factor of risk is this low.

That said, there is a large body of literature pointing out the flaws with the current government-run crop insurance program in the US. Some of the issues cited are the program providing more subsidies to big farmers compared to small farmers, incentivizing riskier farming practices, its increasing costs over time which are currently costing taxpayers around $6.5 Billion annually, encouraging non environmentally friendly farming practices, and having costlier future projections due to effects of global climate change.[21-25] Perhaps the fact that we still subsidize risk for tobacco production with $20 Million annually might be considered an issue as well. One could argue that subsidizing risk will generally have bad outcomes, and there is a decent economic foundation for that argument. But personally, I don't have the expertise to evaluate the US crop insurance program as a whole, and I am not here to pass judgment. That is a task better left to the agricultural economists. But the fact is that the mentioned issues exist, and these are issues that might encourage change in the program.

Now, do the current insurance subsidies, and the low rates discourage stakeholders from taking part in vertical farming? Theoretically speaking, that should be the case. As of now, however, there is no empirical evidence for the notion. Plus, considering the current high production costs and low variety of produced crops, the insurance and subsidy rates are probably not the priority problem blocking vertical farming's progress. Still, if at any point in the future, the insurance rates increase due to global climate change or new legislation deciding to reduce or limit insurance subsidies in any way or form, that would most likely favor more risk-averse forms of agriculture including vertical farming whether it be in the US or anywhere else in the world.

Conclusion

There are various problems associated with our conventional practice of farming. In the past few years alone, agriculture has been responsible for a million square kilometers of deforestation. The world is facing a water crisis, and farming is responsible for using 70% of its freshwater. The prospect of global climate change is projecting a much riskier future to practice conventional farming due to more pesticide incidences, weather uncertainties, changing rain patterns, and more frequent climate extremes. One could argue that these alarming problems might someday be treated as more imminent as the population grows, fertile land availability decreases, the effects of global climate change become more apparent, and the societal concerns for sustainability grows. We could argue that when the costs

associated with the mentioned issues are fully priced in the market, it would be way more expensive to practice conventional farming. Not to mention that it is more likely that the post COVID world would have an increased desire for having locally grown food sources. Perhaps, but we do not know for certain. Either way, the fact is that a new industry of vertical farming businesses has been emerging worldwide in recent years betting on that future. The global industry previously valued at $3.16 Billion in 2018 is projected to reach a staggering $22.07 Billion by 2026. There is a lot of effort dedicated to improving the vertical farming production technology, which is important to the industry's growth. That said, considerable growth in any industry would also require ample effort and investments dedicated to developing a better understanding of the field in terms of economics and business. However, the focus on these aspects of vertical farming has been oddly limited. After researching this aspect of vertical farming for a year to write my master's thesis, I decided to share the most important factors that would help us all form a better understanding of vertical farming as a business practice and what that business could look like in the future.

Author

Faraz Moghimi is a PhD student of finance at University of Massachusetts Boston. Faraz has an engineering background as well, earning his MS and BSc degrees in engineering. His research interests rely on his multi-disciplinary background. In his research, Faraz explores topics related to fintech, application of machine learning in finance, empirical asset pricing, and sustainable technologies. Faraz is currently a TA for the "Asset Management Practicum" MBA course at UMASS Boston, where he teaches the "machine learning in investing" module of the class. He is also a mentor at the Graduate Student Managed Fund in UMASS Boston.
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Endnotes

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