ECONOMIC EVALUATION OF VERTICAL FARMING IN ISTANBUL, TURKEY, BY BLACK SCHOLES REAL OPTION MODEL

(DİKEY TARIMIN İSTANBUL, TÜRKİYE'DE BLACK SCHOLES REEL OPSİYON MODELİ İLE EKONOMİK DEĞERLENDİRİLMESİ)

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LIST OF SYMBOLS

FAO	: Food and Agriculture organization
MNS	: Mineral Nutrition Solution
NFT	**:** Nutrition Film Technique
NPV	**:** Net Present Value
CAPEX	**:** Capital Expenses
OPEX	: Operational Expenditures

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ABSTRACT

The rapid increase in the population and the trend of urbanization in the world create the danger that a food crisis may be encountered in the future. In addition, reasons such as climate change and degradation of farmlands increase this concern. For these reasons, new agriculture methods are gaining popularity. Vertical farming practices, which is one of these methods, are rapidly becoming widespread nowadays. Although there are many studies on vertical farming practices in the literature, there is a need for special studies to evaluate its' regional competitiveness in the market. In this thesis, we examined the economic feasibility of a mid-scale 200 square meter hypothetical vertical farming investment in Istanbul. Since the inputs and outputs were determined in the studies on lettuce cultivation in the literature, we assumed that our facility produces lettuce. In the study we conducted on the high selling price of wholesale market with the Net Present Value method, we concluded that our production facility was almost at the break-even point in the 10-year production period, and that it could be more profitable with the Black-Scholes method. However, since vertical farming products priced higher, more positive, and promising results have been obtained with both NPV and Black-Scholes method in the scenario where we work on higher sales prices than wholesale prices. In the light of the data we have obtained, we have concluded that, although it requires additional research, investments such as existing profitable facilities around the world, would be economically efficient in Turkey as well.

ÖZET

Dünyadaki hızlı nüfus artışı ve şehirleşme trendi, gelecekte bir gıda kriziyle karşılaşılması tehlikesini yaratıyor. Ayrıca iklim değişikliği, tarım arazilerinin bozulması gibi nedenler de bu endişeyi artırıyor. Bu nedenlerle yeni tarım yöntemleri popülerlik kazanıyor. Bu yöntemlerden biri olan dikey tarım uygulamaları günümüzde hızla yaygınlaşmaktadır. Dikey tarım uygulamaları, geleneksel tarım uygulamalarına göre cazip avantajlara sahiptir. Bununla birlikte, bazı dezavantajları da vardır. Literatürde dikey tarım ile ilgili çok sayıda çalışma olmasına rağmen, bölgesel olarak pazardaki rekabet gücünü değerlendirmek için özel çalışmalara ihtiyaç vardır. Bu tezde, İstanbul'da orta ölçekli 200 metrekarelik teorik bir dikey tarım yatırımının ekonomik fizibilitesini inceledik. Literatürde marul yetiştiriciliği ile ilgili yapılan çalışmalarda girdi ve çıktılar belirlendiği için tesisimizin marul ürettiğini varsaydık. Öncelikle Net Bugünkü Değer yöntemini ve ardından Black-Scholes yöntemini kullanarak bir ekonomik fizibilite çalışması yaptık. Literatürde de belirtildiği üzere yatırım ve faaliyet giderleri yüksek olması sebebiyle, birim başına üretim maliyeti de yüksek olmaktadır. Faaliyet giderlerinin yaklaşık yüzde 75'ini elektrik gideri oluşturmaktadır. Net Bugünkü Değer yöntemi ile toptan hal fiyatlarındaki yüksek satış fiyatı üzerinden yaptığımız çalışmada üretim tesisimizin 10 yıllık üretim sürecinde neredeyse başa baş noktasında olduğunu, Black-Scholes yöntemiyle ise daha karlı olabileceği sonucuna vardık. Ancak dikey tarım ürünleri piyasada toptan fiyatlarla rekabetten ziyade daha yüksek fiyatlarla kendilerine pazar oluşturduklarından dolayı toptan fiyatlardan daha yüksek satış fiyatı üzerinden çalıştığımız senaryoda hem Net Bugünkü Değer hem de Black-Scholes yöntemiyle daha olumlu ve umut verici sonuçlar elde edilmiştir. Elde ettiğimiz veriler ışığında, ilave araştırmalar gerektirse de dünya çapında mevcut karlı tesisler gibi yatırımların Türkiye'de de ekonomik olarak verimli olacağı kanaatine vardık.

1. INTRODUCTION

The world population is rising. By 2030 a ten percent and by 2050 with more than twenty five percent increase, the population is estimated to reach 9.7 billion by the United Nation (2015). As the population grows, so does the need for food. Food and Agriculture Organization (2009) reports that by 2050 food production must be increased at least by sixty percent in order to prevent hunger. Food production, especially agricultural production, depends on soil. So, to ensure a growth in production, there has to be a boost in productivity or new cropland must be introduced. However, increasing the productivity does not seem as an option because of degradation of arable land, by natural or man-made causes such as desertification, salinization, compaction, or invasive species invasion (Gibbs & Salmon, 2015). FAO stated that thirty-three percent of world's soil is degraded from moderate to high (FAO & ITPS, 2015). Also, expanding arable land is a concern because of deforestation, which has ecological impacts such as climate change, increase in greenhouse gases, temperature increases, spread of zoonotic diseases and extinction of species (FAO & UNEP, 2020).

Food production is also adversely affected by the consequences of climate change such as droughts, floods, and temperature fluctuations (Parker et al., 2019). However, agricultural processes are responsible for one fifth of the greenhouse gases thus also for climate change (FAO, 2021). Water is also one of the main sources of agricultural production, which accounts for seventy percent of annual water consumption (FAO, 2017). However, agricultural production could be threatened in the future as water resources are threatened by climate change and excessive water consumption (United Nations, 2022).

Food loss is also another problem that decreases overall productivity. Excluding retail and consumption-level losses, more than a fifth of fruit and vegetables were wasted from harvest to retailer in 2016 (FAO, 2019). Urbanization, which United Nations (2018) estimates sixty-seven percent of population by 2050, is also increasing the risk of food lost, due to the need for storing and transporting agricultural products from agricultural areas to urban areas.

Due to the threats on conventional agriculture, new cultivation methods are gaining fame (FAO, 2018). One of them is indoor vertical farming, which is the subject of our thesis, that is not affected by negative impacts such as climate change, desertification, and water scarcity, and does not cause transport losses.

The research conducted by Türkeş et al. (2019) shows that Turkey is facing a serious risk of desertification, and 12.7% of its lands are in the low risk group, 53.2% in the medium risk group and 25.5% in the high risk group 2019. In addition, with rising oil and fertilizer prices, transportation and cultivation costs are increasing, which affects the prices of agricultural products. For this reason, more sustainable and efficient agricultural practices are also needed in Turkey to continue production and lower agricultural product prices.

Therefore, in this thesis, we will examine the profitability of vertical farming in Istanbul, the most populous province of Turkey and dependent on other cities for agricultural products.

2. LITERATURE REVIEW

Vertical farming as the name implies is a farming practice where plants are stacked upward. As plant growth, hydroponic, aeroponic or aquaponic systems, that are known as soilless farming practices, are used. Gilbert Bailey wrote the Vertical Farming book in 1915. Although the concept is old, its reputation has been increasing recently. However, in 2018, the total market value was nearly 2 billion USD, of which approximately 1 billion USD was in North America (PR Newswire, 2019).

Vertical farms are spreading especially in the USA, Europe, Canada, and Japan. Plenty (USA), Jeff Bezos and Walmart are the known investors, Green Spirit Farms (USA), VertiCrop (Canada), Lufa Farms (Canada), PlantLab (Holland), Ikea (Sweden), Green Sense Farms (China), Nuvege (Japan), Sky Greens (Singapore) are some examples of vertical farms, and the numbers are increasing rapidly (Al-Kodmany, 2018; Butturini & Marcelis, 2019).

As vertical farms are gaining reputation and the numbers are increasing, economic evaluation of vertical farms in contrast with greenhouses or field production for different countries are studied. For instance, Dafni investigates the potential of greenhouse cultivation compared to vertical farming in urban areas of Denmark. Internal rate of return (IRR) and net present value (NPV) were used to compare the two production models. The result of the study is that vertical farming is more profitable for investors (Avgoustaki & Xydis, 2020).

In another study, Schweitzer (2020) conducts research to increase the use of vacant properties. He evaluates vertical farming as an alternative. To evaluate economic feasibility from a real estate investor's perspective, he uses the return-on-investment model. As a case study, he chooses Holyoke in higher-income western Massachusetts and

Somerville in lower-income eastern Massachusetts. He concludes that vertical farming has more potential in lower income areas than in higher income areas.

Trimbo (2019) studied economic feasibility of vertical farming in Brazil in contrast to USA. Because of low market prices and higher production costs he concludes that vertical farms in Brazil would not be feasible.

In this paper, we analyze the economic feasibility of vertical farms in Istanbul by Black-Scholes model with the theoretical data used in previous papers.

2.1 Vertical Farming

Vertical farming is vegetable production system in which, instead of conventional farming methods, soilless farming practices such as hydroponic, aeroponic and aquaponic are used. In all these methods, instead of arable lands, green houses or indoor controlled environments are used. For indoor applications, warehouses, home basements and shipping containers can be used. Because in indoor applications, lighting, temperature, humidity, air flow and all the nutrition that is needed for a plant are controlled. The plant growth is speed up and maintains uniformly year-round without affected by the outside climate.

Hydroponic is a farming method in which instead of soil, water-based media is used as shown in Figure 2.1. Plants are planted on substrates such as rock wool, or polystyrene based materials and their roots are suspended into the water which is air rich and nutritionally balanced.

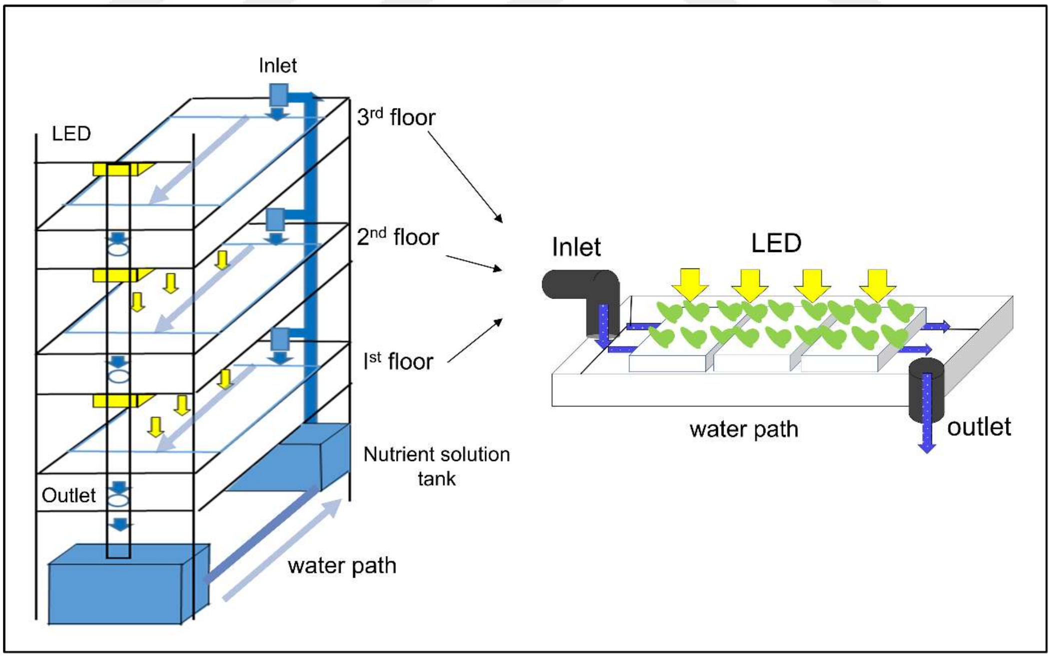

Figure 2.1 Indoor Hydroponic Farming Diagram (Lee, Ju at al, 2017)

In aeroponic farming plants are planted on rigid platforms so that plants roots are suspended in the air. Nutritional water is sprayed to the roots on a regular basis.

In aquaponics, both plants and fish are cultivated. For planting both hydroponic or aeroponic systems can be used and the fish are fed in nursery such as culture fishing and their manured water used as irrigation water instead of nutritional water.

2.1.1 Advantages

Traditional farming practices are seasonal. Also affected by the climate change, heavy rain, hail, storms, or droughts also, decreases the conventional farming yields. However, vertical farms do not depend on external weather conditions. Vertical farms are called plant factories because they can work indoors where production systems such as lighting, air conditioning, irrigation can be controlled automatically (Kozai et al., 2015). As all the necessities for plant grow are artificially provided, year-round high and uniform production can be achieved (Graamans et al., 2018). It also allows vertical farms to cultivate off season products. In addition, due to the vertical stacking of the layers, the production efficiency per square meter in vertical farming is higher than in traditional applications.

In vertical farming, essential minerals and nutrients are delivered to the plant roots by water, called mineral nutrition solution. This reduces water usage to one-tenth of conventional farming (Van Gerrewey et al., 2022). Even in some applications, the reduction in water usage can be as much as ninety-nine percent by water purification, humidity collection etc. (Al-Kodmany, 2018). This is an important issue because the World Bank has stated that agriculture is currently responsible for 70 percent of all freshwater withdrawals worldwide (FAO, 2017).

Indoor farming and mineral nutrition water usage also reduces or even prohibits herbicide and pesticide consumption (Benke & Tomkins, 2017). Pesticides lead to the death of non-targeted animal species even humans and contamination of groundwater (Emilie, 2018).

Indoor hydroponics can be grown in urban areas such as containers, vacant stores, warehouses, or even industrial facilities. This minimizes transportation costs and losses associated with transportation (Al-Kodmany, 2018). In addition, production in urban areas gives growers the opportunity to reach consumers directly.

In vertical farming plant growing layers are stacked vertically, and indoor control environment decreases the growing time of plants. So, the total efficiency of a square meter is increased.

2.1.2 Disadvantages

In vertical farming, the environment is controlled. To provide necessities such as lighting, temperature, humidity, MNS, pH and other parameters, there is a need for technical equipment which increases the investment costs. Even an investment in a high-tech greenhouse cost only one-tenth that of a vertical farm, and running costs are only one-fifth that of a vertical farm (Butturini & Marcelis, 2019).

To properly maintain the necessities especially the artificial lighting and climatization, electricity is needed, which can be a major expense in the operational costs for vertical farms.

In the urban areas, the rents are higher than rural areas especially from the arable lands which increases the operational costs. Therefore, choosing the right location is crucial to reduce operating costs.

Vertical farming requires skilled labor because the chemical and the environment must be checked properly also, plants' growth must be monitored, and the adjustments must be done precisely. To overcome these difficulties the Internet of Things and other smart solutions are being used.

3. ECONOMIC EVALUATION

Besides the environmental advantages, feasibility of vertical farming in urban areas of Turkey must be evaluated by engineering economic tools.

The tools that we are using for feasibility analysis are,

Net Present Value (NPV); is a tool that is used to determine whether an investment or project is feasible or not. The calculation is done by discounting all expected cash flows to the beginning of the project period.

The formula is given as,

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t} \tag{1}$$

Where Rt is the cash flow at the end of period t,
i is the effective interest rate per period,
t is the number of time periods.

Results greater than zero for a single investment project indicates the investment or project is feasible.

Internal Rate of Return (IRR); it is a discount rate which equates the Net Present Value of all cash flows to zero.

$$0 = \text{NPV} = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0 \qquad (2)$$

The net cash inflow during the period t is showed by C_t,
The total initial investment is showed by C_0,
the number of time periods is represented by t.

For results greater than minimum attractive rate of return (MARR), for a single project, project is feasible.

Black – Scholes model, the value of call option, C, is calculated by,

$$C = SN(d_1) - Ke^{-rT}N(d_2) \qquad (3)$$

$$d_1 = \frac{1}{\sigma\sqrt{T}}\left[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T\right] \qquad (4)$$

$$d_2 = d_1 - \sigma\sqrt{T} \qquad (5)$$

Where, k is the exercise price,
S is the underlying asset value,
T is the lifetime of the project,
σ is the volatility,
r is the risk-free interest rate,
and N(d) is the cumulative standard normal function.

4. METHODS AND ASSUMPTIONS

In our study, we supposed that we have a two hundred square meters hypothetical production facility with ten meters width, twenty meters length and four meters height. Sixty percent of the base area can be used for plant production. Forty percent of the area is used for other activities such as seedling, transplanting, packaging, and spacing between growth platforms. With four laid up production layers total cultivation area is reached four hundred and eighty square meters.

In order to achieve a higher thermal resistance with an R-value of thirteen, five-centimeter polystyrene foam blocks are used in the vertical farms (Graamans et al., 2018). In our production facility, we have four hundred and forty square meters inner wall and roof area for insulation. For growth platforms, we calculated the manufacturing cost of four-storeyed platforms consist of pvc pipes and metal bars.

As the vertical farms are closed systems with high insulation levels, the equipment necessities such as air conditioner, pump and led lightings are similar for different facilities in different regions. Energy consumption of these facilities are also similar. Graaman (2018) made a comparative study for vertical farms on three different climate regions which are Sweden, Netherlands, and United Arab Emirates. They used DesignBuilder 2016 program to calculate energy consumptions of the vertical farms for producing 1-kilogram dry weight of Lettuce. The results are 240 kWhe, 247 kWhe and 280 kWhe for Sweden, Netherlands, and United Arab Emirates, respectively. As Turkeys' climate is more likely to Netherlands' climate, we take 260 kWhe consumption for production of 1-kilogram dry weight, for our production facility (Graamans et al., 2018).

For the equipment, with the capacities that is given in Luuk Graamans' paper, we found alternatives that are available on the market.

The output of a vertical farm is given nearly 540 heads of lettuce per square meter per year (Graamans et al., 2018).

General assumptions given in table 4.1.

Table 4.1. General Assumptions

		Unit
Building		
Size W/L/H	10/20/4	m
Stacking Layers/Cultivable area	4 / 480	layers / m^2
Planting density	42	Plant/m^2
Insulation	13,50	USD/m^2
Growth Platform	125,00	USD
Air Conditioner[1]	5.000,00	USD
Led Light[2]	280,00	USD/m^2
Electrical infrastructure	25.000,00	USD
Pump[3]	1.000,00	USD
Plumbing	1.000,00	USD
Other Equipment	1.000,00	USD
Yield	540	Heads/m^2/year

1 Frigotek FMC-3 Chiller and Alda AFC-20 Fancoil suitable for 200 square meters
2 Philips GreenPower LED toplighting
3 Etna EILR4 40-160/0,55 in-line pump suitable for 200 square meters

With todays' prices total capital expenses and total operational expenditures are calculated as given in the tables 4.2 and 4.3.

Table 4.2. Total Capital Expense (CAPEX)

		Unit
Insulation	6.000,00	USD
Growth Platform	60.000,00	USD
Air Conditioner	5.000,00	USD
Led Lighting and Wiring	160.000,00	USD
Pump	1.000,00	USD
Plumbing	1.000,00	USD
Equipment	1.000,00	USD
Total	234.000,00	USD

Table 4.3. Total Operational Expenditures (OPEX)

		Unit
Labor	9.200,00	USD/year
Rent[1]	11.000,00	USD/year
Electricity	99.000,00	USD/year
Water	250,00	USD/year
Equipment	4.000,00	USD/year
Maintenance	6.000,00	USD/year
Total	129.450,00	USD/year

[1] Endeksa

5. CALCULATIONS

To evaluate vertical farming, we examine four different scenarios based on the selling price of a head lettuce. We take the lowest (SC1) and highest (SC3) wholesale prices from Istanbul Metropolitan Municipality website (Istanbul wholesale prices 2023). We calculate a mid-price (SC2) which is average of the lowest and highest price, and we also use a price that is higher than the highest price (SC4). This fourth price is taken because the vertical farms are generally do not compete with wholesale prices. Vertical farms market their products to hotels, restaurants and to the end users with higher prices.

The yield of our vertical farm is calculated by our total cultivable are multiplied by average yield of head lettuce per square meter per year.

In calculating NPV, we used the real interest rate instead of the effective interest rate because we assumed that the annual cash flows are same for each year, regardless of inflation. Since the real interest rate depends on the expected inflation rate, we obtained the expected inflation rate from the market participant survey of the Central Bank of the Republic of Turkey's (TCMB market participant survey, 2023). Also, we took the expected dollar exchange rate from the market participant survey, because we did all the calculations in US dollars. The results are presented in **Table 5.1.**

Table 5.1. Calculations for hypothetical Vertical Farm

	SC1	SC2	SC3	SC4	Unit
Inflation Rate	0,057	0,057	0,057	0,057	
Real Interest Rate	0,031	0,031	0,031	0,031	
Annual Income	106.122,45	132.653,06	159.183,67	198.979,59	USD
Annual OPEX	129450	129450	129450	129450	USD
Price/Head	0,41	0,51	0,61	0,77	USD
Cost/Head	0,50	0,50	0,50	0,50	USD
Total Investment	234.000,00	234.000,00	234.000,00	234.000,00	USD
Nominal Rate	0,09	0,09	0,09	0,09	
NPV	-419.038,46	-206.873,57	17.811,73	354.839,68	USD
Payback Period	-	-	9,5	4,5	Years
Project IRR	-	-	5 %	27 %	

5.1 BLACK-SCHOLES MODEL

Black-sholes is one of the real options evaluation methods, used for pricing financial and investment options. It is based on the strike value, the underlying asset value, lifetime, volatility, and risk-free rate. The model is built on NPV analysis.

In our study, as the underlying asset value, we used net annual cash flows that we have already calculated at NPV model. The strike price or the exercise price is the total investment that has to be made to start the facility to operate. Time to expiration is 120 months. Volatility is calculated from the wholesale market hall prices given by Istanbul Municipality. It is given from January 2020. And the risk-free annual interest rate is taken nine percent.

We also calculated expanded NPV, which is uncertainty adapted NPV, by addition of standard NPV and option value.

The results, given in table 5.2.1, are higher than the NPV analysis as expected.

Table 5.1.1. Calculations of Black-Scholes model

	SC1	SC2	SC3	SC4	Unit
Underlying Asset Value	-197.558,87	27.126,43	251.811,73	588.839,68	USD
Exercise Price	234.000,00	234.000,00	234.000,00	234.000,00	USD
Time to Expiration	120	120	120	120	Months
Volatility	0,00793	0,00793	0,017556	0,017556	
Risk Free İnterest rate	0,0075	0,0075	0,0075	0,0075	
Call Option	-	877,98	173.296,76	493.673,25	USD
Expanded NPV	-419.038,46	-205.995,58	191.108,39	848.512,93	USD

6. DISCUSSION

In this thesis, we analyze economic feasibility of a small size vertical farm in Istanbul, Turkey. In hypothetical production facility of 200 square meters with a total of 480 square meters cultivable area. In the paper written by Graamans et al. (2018) it is given that 540 head of lettuce can be grown from a square meter of area per year. They used 190 watts of led lighting per square meter. Total electric energy requirement consists of equipment, cooling and artificial lighting of a head lettuce is 2,36 kilowatts. In Turkey with today's electric price energy cost of head lettuce is 0,37 USD. With additional operational costs, the production cost of a head lettuce is 0,50 USD. The marketing price under 0,50 USD, makes the annual cash flows negative. Prices in between 0,50 USD and 0,70 USD make the annual cash flows positive however, vertical farming seems infeasible with NPV analyses because of the high investment cost. Prices higher than 0,70 USD make the project feasible.

As the NPV analyses implied negative results, we used reel options as a second tool. We used Black-Scholes model to analyze the economic feasibility of our hypothetical vertical farm. The results look promising. Marketing prices higher than 0,50 USD, the production cost of a head lettuce, makes the project feasible.

The vertical farms around the World do not compete with wholesale prices, they are marketing at higher prices. Because vertical farmed products are fresh, clean and the production is uniform year-round. Their market is hotels, restaurants, and end-users. So, for our 200 square meter local production facility, restaurants, hotels, and end-users around the facility will be the prior market. So that, selling price would be higher not just from wholesale prices but also than groceries. Which makes vertical farming profitable.

Vertical farming is electric dependent. Electricity used for equipment, cooling and artificial lighting is nearly 75% of the total cost. As the turkeys' electric production is changing to renewable energy sources, which is already more than half of total production, would lead a drop in energy prices in future. Thus, production cost of a head lettuce would fall in price.

Vertical farms, operated around the World, are producing multiple crops instead of single crop. Hotels and restaurants work with these farms for all the greens that they produce, which inhibits the over production of single variety. Products which are produced more than marketable size have to compete with wholesale prices, which decreases the profit.

Vertical farms also work with off-season crops. As the conditions can be set artificially, producing off-season products increases revenue because of higher prices.

In our study, we want to examine a base scenario with a single crop competing with wholesale market. This study shows that even a mono-crop production facility, competing with wholesale prices can survive. Which means that a well-organized vertical farm working with hotels and restaurants, as same as the best practices around the world, can be a feasible investment.

7. CONCLUSION

Increasing population and losing cultivable lands tends people to find new cultivation techniques with less carbon footprint. Vertical farming is a production method which enables soilless plant growth with far less water usage. This technique also provides year-round production with a higher yield. There are lots of vertical farming companies, at different scales, around the world maintaining their production and their numbers are increasing day by day. However, there are also some concerns about the economic feasibility of these farms because of higher investment and operational costs. In the literature there are some studies that are evaluating economic feasibility of vertical farming for different countries. In this thesis, we analyzed economic feasibility of vertical farming in Istanbul, Turkey.

The first method that we used is the NPV method. In NPV analyses the result implied that for profitability the price of a head lettuce must be higher than wholesale prices. Secondly, we examined our vertical farm by Black-Scholes model. The results of the Black Scholes model looked promising. Even prices slightly higher than the production cost makes the investment profitable.

Therefore, we concluded that best practices would be far more profitable if a single crop production facility was viable.

7.1 Limitations and Future Work

Since almost all the articles in the literature work on lettuce production, the input and output data of vertically grown lettuce are defined. For this reason, in our thesis, we used lettuce as a single product to make economic evaluations. However, vertical farming companies work with more than one product. They work especially with high value-added, off-season products. Therefore, the production of other species should be included to study the economics of vertical farming. In order to overcome this problem, data sets should be created from studies accepted in the literature.

In future work, vertical farms, which produce more variety, can be studied. Because that will give a better understanding of the economics of vertical farms. Also, distribution of vertical farmed products from facility to the end-users such as hotels and restaurants can be examined economically. In addition to, marketing and transportation costs, the profit margin would also increase.

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APPENDICES

Appendix A.

05.2023 Exchange Rate	19,6
05.2024 Expected Exchange Rate	24,08
12 months Expected Inflation Rate	29,84
12 months Calculated Inflation (USD)	5,68

Appendix B.

	SC1	SC2	SC3	SC4
Price per Head	0,408163265	0,51	0,61	0,765
Investment Cost	-$221.479,59	-$234.000,00	-$234.000,00	-$234.000,00
Annual Cash Flow -1	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -2	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -3	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -4	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -5	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -6	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -7	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -8	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -9	-23.327,55	3.203,06	29.733,67	69.529,59
Annual Cash Flow -10	-23.327,55	3.203,06	29.733,67	69.529,59
NPV	-$419.038,46	-$206.873,57	$17.811,73	$354.839,68

Appendix C.

Date	Higher price (TL)	Lower Price (TL)	Exchange Rate	Higher Price ($)	Lower Price ($)
May-23	12	8	19,59	0,612498	0,408332
April-23	12	8	19,35	0,620222	0,413482
March-23	15	7	19,02	0,788805	0,368109
February-23	12	7	18,86	0,63623	0,371134
January-23	15	7	18,80	0,798068	0,372432
December-22	11	6	18,67	0,589051	0,321301
November-22	7	6	18,63	0,375825	0,322136
October-22	7	6	18,60	0,376334	0,322572
September-22	7	4	18,33	0,381881	0,218218
August-22	5	4	18,04	0,277162	0,221729
July-22	8	4	17,50	0,457172	0,228586
June-22	8	4	17,01	0,470375	0,235188
May-22	8	4	15,74	0,50822	0,25411
April-22	8	4	14,72	0,543585	0,271793
March-22	8	4	14,63	0,54693	0,273465
February-22	8	4	13,67	0,585347	0,292674
January-22	7	3	13,55	0,516716	0,22145
December-21	5	3	13,57	0,368463	0,221078
November-21	5	3	10,70	0,467303	0,280382
October-21	5	3	9,17	0,545244	0,327147
September-21	5	3	8,55	0,584563	0,350738
August-21	5	3	8,49	0,589227	0,353536
July-21	3	2	8,62	0,348101	0,232067
June-21	3	2	8,62	0,348012	0,232008
May-21	5	2	8,38	0,596922	0,238769
April-21	6	3	8,17	0,734826	0,367413
March-21	4	3	7,68	0,520589	0,390442
February-21	4	3	7,09	0,564366	0,423274
January-21	5	3	7,40	0,675457	0,405274
December-20	5	3	7,72	0,647761	0,388656
November-20	4	2	7,99	0,500438	0,250219
October-20	4	2	7,90	0,506105	0,253052
September-20	4	1	7,54	0,530455	0,132614
August-20	2	1	7,28	0,274548	0,137274
July-20	2	1	6,86	0,291384	0,145692
June-20	1,5	1	6,82	0,219864	0,146576
May-20	3	1	6,96	0,431332	0,143777
April-20	3	1	6,85	0,437931	0,145977
March-20	3	1	6,34	0,473074	0,157691
February-20	3	1	6,07	0,494389	0,164796
January-20	3	1	5,93	0,505877	0,168626
variance	11,384295	4,091612		0,017556	0,00793
Stan. Dev.	3,4159775	2,047902		0,134144	0,090154

Appendix D.

	SC1	SC2	SC3	SC4
d1	-	-1,6925	0,7718	1,3499
d2	-	-2,6801	-0,6976	-0,1195
C(St,t)	-	\$877,9843	\$173.296,6715	\$493.673,2563

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