Vertical Farming Smart Agriculture for Smart Cities

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Abstract—Today with such a rapid increase in population and their food demand it is essential to focus on production of food. With very limited amount of arable land left and also the scarcity of other resources required for farming such as water it is the need of world to implement some technology that would overcome the various barriers in the way to accomplish the goal of providing food and nutrients to the whole population. In this paper, we discuss one such technology which would help improve the food production rate. Vertical farming is the technology which uses smart aeroponics, smart light, smart nutrition, smart data, smart substrate, smart pest management and smart scaling which all together can make an area especially urban areas smart leading to removal of barriers in nutrient supply to society and hence achieving the goal of smart city.
Keywords—vertical farming; aeroponics; smart city

I. INTRODUCTION

The basic needs of human are food, clothes and shelter. Food is an essential part of everyone's lives. Food provides the essential energy and nutrients that help the beings grow and develop, work, learn, play and think. But today there is need to think about the production of the most basic need of human being that is food.

Continued population growth and increasing incomes have led to increasing food demand. With a current annual population increase of more than 80 million and an expected increase from the current 7.5 billion to about 9.5 billion people by 2050, the world population will require about 50% more food by 2050. Also more than half of the population of developing countries now resides in urban areas and estimates are that it will increase to two-thirds by 2050. [5]

A very large number of people suffer from micronutrient deficiencies and the health problems they cause. Given the serious health consequences, it is fair to characterize this as a serious global public health problem. Unfortunately, large shares of poor and non-poor urban households in both high and low-income countries do not have regular, daily, year-round access to fresh vegetables at prices they can afford. The so-called "urban food deserts" is the extreme case. But in many other urban areas, poorly functioning supply chains, seasonality, production and price volatility and other supply-factors mean that fresh vegetables are out of physical or economic reach to many millions of urban households or only available on an random basis and at high costs. [2]

The production of vegetables in open fields is associated with large risks and uncertainties from biotic and abiotic stresses, such as pest attacks, droughts, floods and strong winds. Climate change and associated irregular weather patterns and extreme weather events add to these uncertainties. Use of pesticides may introduce real and/or perceived health risks. [4] The supply chain for vegetables produced in open fields or greenhouses is frequently long for the obvious reason that land is required for cultivation. Infrastructure investments, CO_2 emissions and related energy expenditures in transportation may be large.

Climate change and related extreme weather events are causing higher risks and uncertainty in agricultural production. Increasing temperature brings new pests and plant diseases for which solutions may not be available. Higher frequency of extreme weather events are resulting in large production fluctuations with frequent crop losses, large yield variations and volatile food prices. Production of vegetables in open fields is particularly volatile. As climate change proceeds, the benefits from enhanced control of the production environment will be even more obvious to assure a continued supply of a diversified portfolio of foods to meet nutritional needs. While insurance schemes and subsidies may help protect farmers and consumers from excessive food price volatility, they do not reduce production fluctuations. Cities are now expanding their roots to the arable lands too. And this is the reason why there is need of turning around towards innovative approaches such as vertical farming to deal with farmland shortage. Vertical indoor vegetable production can help expand the supply and lower prices. At the same time, it can relieve the pressure placed on land, water and biodiversity by the increasing food demand. [7]

II. CONCEPT

Vertical farming is the practice of growing leafy vegetables, fruits and some more veggie products in vertically stacked layers. The practice can use hydroponic or aeroponic growing methods. Vertical farms help to produce food in challenging environments, like in the areas where arable lands are unavailable. The method helps deserts and urban areas grow different types of fruits and vegetables by using precision agriculture methods. [6] Hydroponic methods have a growing medium replacing soil and hence reducing weight and also lower the water requirements up to an appraising level, leading to a great solution to save space. Most vertical farms are either hydroponic or aeroponic. A solution is used which is spread onto the roots to provide the essential nutrients. A special fabric helps roots and plants grow in a healthy way. Also a mix of natural light and artificial light is used where artificial lighting is LED-based and may be driven by a renewable power source such as solar power. [2]

III. METHODOLOGY

Aeroponic planting is unlike other hydroponic or soil-less planting methods which include ebb and flow, pond, and aggregate planting methods. In the ebb and flow method, the roots are periodically submersed in liquid nutrients. In the pond culture method, the roots are suspended in a solution of liquid nutrients, which is generally oxygenated. In the aggregate planting method, the liquid nutrients are supplied to plants in a non-soil containing aggregate. Because plants require oxygen to their roots, hydroponic methods are designed to provide both oxygen and liquid nutrient to nourish the plants. In Aeroponics the nutrient solution liquid is sprayed on to the roots of the plants which are suspended in the chamber. [14]

The practice of aeroponic farming includes depositing of the plant seeds in a flat containing micro-fleece cloth. Then the flat is placed within a growth chamber. The upper side of the flat is exposed to light of the proper frequencies to ensure proper photosynthesis in plants and hence the growth in plants. A nutrient solution liquid is sprayed onto the micro-fleece cloth and the growing roots of plants. And along with this process the temperature, humidity, and carbon dioxide content in the growth chamber is also controlled and maintained. The plants are harvested at a desired stage of growth. The growth chambers can be stacked on each other and/or can also be located side by side to save space, and hence making it possible to share the subsystems that control the nutrient solution, temperature, humidity, and carbon dioxide within the growth chambers. [3]

The practice of aeroponic farming includes the following steps:

depositing seeds in at least one flat containing micro-fleece cloth;

positioning at least one flat within a growth chamber;

exposing an upper side of at least one flat to light of the proper frequencies to promote photosynthesis in plants;

Spraying a nutrient solution liquid onto the micro-fleece cloth and the growing roots of the plants.

A cloth flat for seed germination includes a large number of strips of micro-fleece cloth sewn together to form a large number of furrows set crosswise that remain closed when tension is applied orthogonal to the furrows, by which when un-germinated seeds are positioned within the furrows, the closed furrows protect the un-germinated seeds from direct light. [1]

To ensure proper growth of plants some design areas should be facilitated and controlled as mentioned below.

Availability of light: Supplying light to plants of the right wavelengths is essential. Typically fluorescent, metal halide and high-pressure sodium (HPS) are used for lighting and may be used as supplement to sunlight or also as the only source of light. Metal halides apparently support vegetative growth better. HPS apparently supports flowering stages better. Different lights have varying lifetimes, therefore economic considerations for maintenance and replacement should be considered. Lights can be inefficient regarding to excess heat production. Handling this heat production involves air movement as well as water-jacketing. The light and nutritional needs of plants during germination, growth, and flowering stages vary, that is, light requirements vary among different species of plants. Many plants require a dark period daily or periodically in order to ensure normal growth or a pre-harvest dark period for enhancement of plant characteristics including enhanced flavor and color. [7]

Space optimization: Plants are arranged in ways that include vertical stacking or transplanting from minor allocations of space to major as required by the plant during its growth period. The special features modules which are trapezoidal modules are arranged so that adjacent units run in opposite directions. Also the modules can be stacked on each other indefinitely, with some changes required only when introducing new plants and harvesting plants that have reached their desired stage of growth. [8]

Providing best environment for roots: Light is not promotable for roots. Drying of roots is the sign of danger to healthy plants. The separation of the root and plant zones should also be considered. Nutrients that land on plant flora may alter the appearance and taste of final product. Also excess nutrient due to spraying promote algae growth and may aid the spread of disease. [9]

Preventing pests: Pesticides should be avoided as they damage the plant quality. So, instead of pesticides screening method can be used to help with exclusion, and also insect predators can be used as a means of pest control. [9]

Reducing humidity: High humidity indirectly causes tip burn in leafy plants and hence causing death of leaves at their perimeter. The actual cause for this is believed to be a lack of sufficient calcium at the edges of the growing leaf due to insufficient plant transpiration. Lowering the humidity can lead to an increased transpiration and hence more calcium will be available to the cells at the leaf edges. The total light per day is also a contributing factor in causing tip burn, with heat and humidity worsening the tip burn. Tip burn is exposed by a curling and browning of cells at the edges of leaves which is the death of leaves. [7]

Maintaining temperature: Maintaining temperature is essential for germination and growth of plant and this varies among different species of plant. Also this varies during their stages of germination and growth. Most of the leafy vegetables are often cold season crops that require temperatures between the range of 50 degrees F. and 70 degrees F. To reduce excess heat and light from sun or lighting system, actions such as cooling of light bulbs via water-jacketing, nutrient solution cooling or shading techniques can be used. [10]

Provision of labor efficiency: Farming of leafy vegetables is generally automated in some way but labor is used where automated farming and harvesting has not proven satisfactory. Labor is required where the product is affected by some disease or to clean the undesirable remains of the plants. Often dirt and dust may get settled on the plants for example during transportation of the plants. In this case either the producer or the consumer should take the precaution of washing the plants before consuming them. [12]

Nutrient usage optimization: Nutrient solutions are recirculated in many systems for a finite amount of times. Such system is referred to as closed system. While performing replenishment care should be taken regarding the pH, EC (electrical conductivity), and contaminants (organic compounds from roots and organisms growing in solution) in the nutrient solution. Often automated methods are used to retain the properties of the nutrient solution. [11]

Usage of cloth:

The cloth should be uncovered on the upper side, i.e., the side with the seeds and leafy side of the plants. Algae grows on surfaces with cover more rather than on uncovered surfaces. The weight of the cloth is increased with cover on both sides of the cloth. The uncovered side does not support germination well, and depending on the looseness of the weave, does not allow root penetration, and hence causing plants to grow above or below the plane of the main cloth. Cloth is proved to be a suitable medium for the germination purpose but not all the fabrics work satisfactorily. Due to usage of cloth space optimization is gained well. Also the interference of plants amongst themselves should be handled for efficient plant growth. Cloth is especially useful for growing vegetables like salad leafy plants by providing easy handling and automation of cultural methods, and allowing cleaning for cloth reuse. Further, cloth of the appropriate fiber and weave provides proper growing conditions to plants, including access to moisture and support for roots of the plants. Also the cloth provides a separation to part the root zones and flora zones, hence reducing light from the root zone and also removing excess nutrient spray from the flora zone. Cloth may be reused a number of times after harvesting of plants and removal of the roots. Fabrics that allow root penetration and hold water without soaking seeds are able to promote the growth healthy plants. Cloth is preferred due to its water absorbing and reusable properties, its porosity that allows root growth, its construction that prevents the spray from directly penetrating the cloth, its handling properties that facilitate space optimization and machine washing. [13]

IV. ADVANTAGES

The green aspects of the technology include minimal use of water per plant due to spacing and enclosure, little outgoing created as solutions are recycled, reuse of the cloth growth medium, and maximum energy efficiency. Further improvements could be gained from alternative power sources and generation of animal feed from any discarded plant material. Space is optimized according to the plant stage. The root and flora zones of growing plants are separated. Plants are protected from insect. The plant growth medium is reusable.

Cutting water use by 95% is essential when there is increasing water scarcity, decreasing of ground water levels. Water logging and salination of soils, a serious problem in many countries with extensive use of irrigation but lack of appropriate drainage facilities would also be avoided as would water pollution and soil contamination. The plant nutrient efficiency is much higher in indoor aeroponic or aquaponics farming than in open fields. Contamination of lakes and other water resources by fertilizer run-off would not occur. The yields of products are higher and the growing period cycles are shorter when grown with the use of appropriate technology, including the lighting management and a controlled environment.

V. CASE STUDY

5.1 Company name: AeroFarms [15]

This company is practicing the vertical farming method since 2004 in a controlled manner. The way they implement the technology can be adapted to different repurposed industrial spaces. They have a rich farming history of over 10 years that first started up in the Finger Lakes area of New York. They moved their headquarters to Newark in 2015 to be able to serve the New York metro area. The size of their headquarters being 70,000 sq. ft. with a harvest of up to 2 million pounds per year.

AeroFarms grows over 250 different varieties of leafy greens and herbs. They offer standard mixes and custom blends for endless culinary possibilities. Their products have longer shelf life and the highest possible food safety controls from depositing seed to packaging the product.

As shown in fig.1 the solution chambers are stacked vertically on upon other with the nutrient solution in the solution chamber. Then a cloth medium is fixed on which the leafy greens grow such that the roots stay in the nutrient solution chamber and the leafy greens are above the cloth medium. Above that the leafy greens are exposed to the LED light which helps in photosynthesis process.

At the 2017 Seeds & Chips Global Food Innovation Summit in Milan, Italy, AeroFarms was presented with the Best Smart City Vision Award for its contribution to the economic and environmental sustainability of Newark and its potential to affect positive change in cities all over the world.[15]

AeroFarms has been named to the Global Cleantech 100 list. This award is presented to the top companies that represent the most innovative and promising ideas in clean tech and that are best positioned to solve tomorrow's clean technology challenges. [15]

AeroFarms is now a Certified B-Corp. B Corps are for-profit companies certified by the non-profit B Lab to meet rigorous standards of social and environmental performance, accountability, and transparency. [15]

Fig. 1. Vertical Farming at AeroFarms

5.2 Aerofarms 2017 B Impact Report[16]

	Company Score	Median Score
Overall B Score	89	55
Environment	13	7
Environmental products & services (e.g. renewable energy, recycling)	N/A	N/A
Environmental Practices	12	6
Land, Office, Plant	3	3
Energy, Water, Materials	6	1
Emissions, Water, Waste	1	1
Suppliers & Transportation	2	N/A
Workers	14	18
Compensation, Benefits & Training	8	12
Worker Ownership	2	1
Work Environment	4	3

Customers	36	N/A
Customer Products & Services	N/A	N/A
Products & Services	6	N/A
Serving Those in Need	30	N/A
Community	17	17
Community Practices	17	15
Suppliers & Distributors	1	2
Local	2	5
Diversity	2	2
Job Creation	5	2
Civic Engagement & Giving	6	3
Governance	9	6
Accountability	3	3
Transparency	3	3
Overall	89	55

VI. CONCLUSION

Vertical farming is a new and smart way to fulfil the daily and basic food necessities. Vertical farming is an urban replacement of the imported rural agriculture. It introduces the way to implement farming in the urban areas where the space is dense and hence fulfilling the daily nutritional demands of the population. The most important topic of debate which is the depletion of resources essential for cultivation like land, water, labor, all can be overcome in using this technology.

VII. REFERENCES

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