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Urban Vertical Hydroponics

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Abstract

Nowadays, throughout the world, over 80% of the land that is suitable for raising crops is in use. Vertical indoor farming environmental technologies are coming up as emerging technologies for health protection in urban environments. Efficient agroponic systems could provide safe qualitative food and protect environment and public health from long term chemical hazards. By the year 2050, nearly 80% of the earth's population will reside in urban centers. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. A new land of efficient constructions in agroponic systems will be needed to grow enough food to feed human population and live stocks, competing traditional farming practices that continue as they are practiced today.

Keywords: vertical farming; pollution control in irrigation systems; efficient hydroponic systems; indoor farming; nutrients for food; efficient constructions for hydroponic systems; public health.

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1. INTRODUCTION

Vertical farming is a concept that is in its technical infancy but does hold promise for future cities. Further research can help pursue this idea further. This includes developing multifunctional designs with input from engineers, architects, and vertical farming technology providers simultaneously in order to help design future structures that can adapt to 21st century needs, developing pilot programmes where real time data can be collected and analyzed in order to examine where opportunities and barriers exist compared to conventional produce, developing a larger energy model that can take more factors into account (ventilation, waste, etc.), and conducting a techno economic study that incorporates construction and maintenance costs. Vertical farming does hold potential in the right circumstances.

In order to examine the concept of vertical hydroponics an introduction to the idea of hydroponics is considered necessary.

2. HYDROPONIC SYSTEMS FOR PLANT PRODUCTION

Hydroponics is a method to produce agricultural products with soilless means of production. There are several methods of hydroponic systems for plant production. The basic idea is the use of several media on which the plant is growing when a continuous supply of water is used.

In the next photos are displayed the most often hydroponics systems.

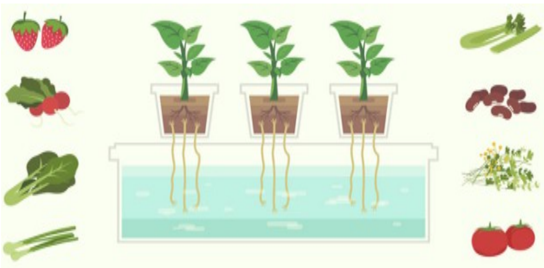

Fig. 2.1 Operational set up of hydroponic systems

Source: [22]

Fig. 2.2 Operational inclined irrigation pipe networks of hydroponic systems

Source: [23]

The photo shows a system of plant production using plastic tubes. The water is circulating through the tubing and is monitored for pH and conductivity.

Fig. 2.3 Compact precast constructions of hydroponic systems

Source: [21]

The roots play the most critical role in a hydroponic system. Part of the roots should be immersed in water while the other part should be in contact with air for oxygenation. In the above scheme the plants are stabilised on a floating panel normally made of PVC or something similar. The roots are immersed in the water which is aerated with the use of an air pump.

Fig. 2.4 Vertical operational constructions in hydroponic systems

Source: [24]

The photo shows a hydroponic system using plastic tubes on a vertical position. Possible this system is more economic in using the available space.

2.1 Hydroponics in the city

Urban farming production of fruits, vegetables, and grains, inside a building in a city or urban centre, in which floors are designed to accommodate certain crops using hydroponics (water with nutrients) [4]. This kind of hydroponics can be raised in buildings or terraces in cities to provide food without the use of soil. This technology can give a prospected solution to the problem of overpopulation predicted to 9 billion by 2050 of which 70% will live in urban centres [16]. If also the changing of climate is considered will bring Earth resources to its limits. As food supply and security is a growing area of concern, solutions to the coming problem should be considered and different technologies should be evaluated. The idea is to produce food to cities in a way that is environmentally friendly and energy efficient [5, 6].

The method to supply food to the cities is also a very important issue to be considered. The food produced should be in the vicinity of the city's market so to reduce the transportation expenses as well as to maintain its freshness. The production of food with the vertical hydroponics could be an option to be considered as the cost of land in the cities is more expensive when used horizontally. This idea could utilize the empty terraces which are plenty and not in any use, in a city, as well as, the construction of buildings of skyscrapers dedicated to hydroponic production of food. The concept of vertical farming is a large scale extension of urban agriculture within a building [2]. There are several authors dealing with the idea of vertical farming. The history of urban agriculture and its reviewing has been studied by [1] who is advocated that vertical farming holds for communities with food security.

Others have provided some architectural designs of how the concept may be developed [9]. The viability of smart technology of vertical farming has been evaluated by Sivamani, Bae and Cho [15]. For the purpose of this proposal the analysis by Malek Al-Chalabi has been considered [10]. The author investigates the feasibility and plausibility of the vertical farming concept from a socio-technical, mixed methods, research perspective in three specific and interrelated research domains. He has examined how much energy is needed to power such a building and whether renewable energy can meet the onsite demands of the building by developing a simplified energy model, he has also determined the carbon footprint of vertically grown produce and subsequently compare that to produce grown conventionally, and he also investigates how relevant stakeholders perceive the concept of vertical farming in order to identify what are current barriers and opportunities exist towards possible uptake of the technology.

Fig. 2.5. Views of vertical systems in urban hydroponics.
Source: [4]

As well as the fact that internet technology and I.C.T's are developed in time new innovative operational solutions are becoming reality in efficient agroponic systems supporting food for humans and feeding live stocks. Hybrid agroponic robust construction systems in cities or islands; open outdoors and indoors spaces could be realized for urban and semi-urban environments respectively having access by road, boats or other means of green transport systems.

Efficient management of nitrogen and phosphorous fertility is one of the most challenging aspects of indoor farming crop production. Effective engineering designs in irrigation and drainage systems as well as innovative systems in biotechnology are necessary so as to avoid long term chemical pollutants from pesticides. Therefore effective hydroponic designs can be applied consuming properly renewable resources from biomass for operational uses in irrigations and drainage avoiding not only emissions of nitrogen and phosphorus concentrations which are hazardous for groundwater pollution, eutrophication in water surface and protection of public health from toxic chemical concentrations but also avoiding expenses for shipment of agricultural goods and their associated atmospheric emissions of air pollutants [2, 7, 8, 11, 12, 13, 14, 17, 18, 19, 20].

3. CONCLUSIONS

In the design, light is used to cultivate the crops inside the building and water is pumped throughout the building for the hydroponic culture. Solar panels are placed on the roof and on the facade (one side). Therefore, using this design as a basis, the energy flows (demand and generation) were quantified. The purpose of quantifying the energy flows was to specifically determine how much energy is needed to power such a building (demand) and whether renewable energy can meet the onsite demands of the building (generation). For the energy demand, the amount of energy required to light the building and pump the water was calculated. Lighting and water pumping are two of the main energy demand items, and was therefore the focus of this research.

For energy generation, the amount of energy generated from solar panels was quantified. Favourable assumptions were made in order to see if this design is possible in a best case scenario. The timeline for the energy flows was over the course of a month. In order to examine the energy flows, an energy optimization model was developed. The reason that an optimization model was developed was because the amount of energy required to power the building is contingent on the building dimensions. When a building occupies a larger area, the lighting and water requirements increase, but so does the amount of energy available (via solar panels on the roof and facade). The opposite is also true – the lighting and water requirements in the building decrease when the building occupies a smaller area, but so does the amount of energy available (less number of solar panels available on roof and facade).

Therefore, different dimensions were examined in the model in order to ascertain the feasibility and plausibility of vertical farming [2]. Engineers in general believe that an old building could be retrofitted to meet the needs of the vertical farm, while architects believe that a new building was required. All were in agreement that costs were an important aspect in deciding whether or not to build the project, and many agreed that this was a novel area and more research was required. A barrier identified is that many perceived hydroponics as ‘food made from chemicals’ and ‘not natural,’ and therefore could be a social barrier towards the uptake of produce grown in cities. An answer can be the purity of water from herbicides and fungicites. The more controllable use of nutrients give a healthier plants.

Most important, hydroponics allows the grower to select where to locate the business, without concern for outdoor environmental conditions such as soil, precipitation or temperature profiles. Indoor farming can take place anywhere that adequate water and energy can be supplied. Sizable hydroponic facilities can be found in the U.K., the Netherlands, Denmark, Germany, New Zealand and other countries. One leading example is the 318-acre Eurofresh Farms in the Arizona desert, which produces large quantities of high-quality tomatoes, cucumbers and peppers 12 months a year. Most of these operations sit in semirural areas, however, where reasonably priced land can be found. Transporting the food for many miles adds cost, consumes fossil fuels, emits carbon dioxide and causes significant spoilage.

Discussion from an energy perspective, the results indicate that vertical farming is feasible in areas that have abundant sunlight. With these conditions, enough energy could be generated to light the building and pump the water. However, with these conditions, the site specific environmental implications of obtaining water from areas that have abundant sunlight should be examined. An area of future research would be to do a techno-economic study of the concept as well as a cost benefit analysis of vertical farming from an energy and produce perspective. Vertically grown produce has a carbon footprint that is much higher than conventionally grown produce.

However, the pilot currently generates energy from conventional sources of energy and it may be competitive compared to conventional produce, but this requires further research. Additionally, a complete life cycle analysis that incorporates the cultivation and nutrient culture would be able to identify where energy savings/losses occur compared to conventional produce. This can help further develop an understanding of where opportunities exist. One issue for debating is if hydroponically grown food is perceived as being 'food made from chemicals' and 'not natural.' This could be a potential obstacle for the uptake of the technology and more research should examine the prons and cons.

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