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Vertical farming: New agricultural approach for 21st century

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Introduction

The world population is predicted to reach an estimated 9 billion by 2050 (Despommier *et al.,* 2013), and cities will be hosting about 80 per cent of total population (Despommier, 2010). VF is the practice of growing crops in vertically stacked layers (Birkby, 2016). VF is a revolutionary and sustainable method of agriculture as it lowers the requirement of water up to 70 per cent and also saves considerable space and soil. It often incorporates farming techniques includes controlled-environment, which aims to optimize plant growth and soil less cultivation such as hydroponics, aquaponics and aeroponics. Some common structures to vertical farming systems include buildings, shipping containers, underground tunnels and abandoned mine shafts. The main advantage of VF techniques is to increase the crop yield from a smaller unit area of land requirement. VF techniques faces economic challenges with large start-up costs as compared to the traditional farming practices. Vertical farms also face large energy input requirement due to the use of supplementary light like LEDs. Moreover, if non-renewable energy is used in vertical farms to meet these energy demands, could produce more pollution than traditional farms or greenhouses.

Techniques of Vertical Farming

Hydroponics

It refers to the technique of growing plants without soil and is a predominant system that is used in vertical farming. In hydroponic systems, growth of plants in solutions of nutrients that are essentially free of soil i.e. the plant roots are submerged in liquid solutions containing macronutrients as well as micronutrients such as nitrogen, phosphorus, sulphur, potassium, calcium and magnesium, as well as trace elements, including iron, chlorine, manganese, boron, zinc, copper and molybdenum. The advantages of hydroponics, increase yield per unit area and reduce water usage.

Aeroponics

It is growing of plants in an air/mist environment with no soil and very little water. By far, aeroponics is the most sustainable soil-less growing techniques, as it uses up to 90 per cent less water than the most efficient conventional hydroponic systems and requires no replacement of growing medium. Moreover, the absence of growing medium allows aeroponic systems to adopt a vertical design, which further saves energy as gravity automatically drains away excess liquid, whereas conventional horizontal hydroponic systems often require water pumps for controlling excess solution. It has also been observed that the plants that are grown with the aeroponic system uptake more vitamins and minerals, thus making the plants potentially healthier and more nutritious. Currently, aeroponic systems have not been widely applied to vertical farming, but are starting to attract significant attention.

Aquaponics

An Ecosystem that promotes plants and fish farming together: The term aquaponics is the combination of two words: aquaculture, which refers to fish farming and hydroponics, the technique of growing plants without soil (Kledal, 2018). This system is much like the hydroponics. Its aim is to combine the fish and plants in the same ecosystem. In this system, fish grow in indoor ponds and produce a nutrient rich waste that further acts as a food source for the plants grown in vertical farms. Nutrient rich waste water from the fish tanks is filtered by a solid removal unit and then led to a bio-filter, where toxic ammonia is converted to nutritious nitrate. Moreover, the plants consume carbon dioxide produced by the fish and water in the fish tanks obtains heat and helps the greenhouse maintain temperature at night to save energy. The plants doing their part by purify and filter the wastewater that gets recycled directly to the fish ponds. Aquaponics is generally used at smaller scale than most vertical farming innovations. However, it is still used by many commercial vertical farms that wish to produce just a few fast-growing crops instead of including the component of aquaponics. As a result, the production and economics issues are simplified and it also maximizes efficiency.

Aero Farms

Aero Farms consist of innovation by using the aeroponic system of farming that ensures predictable results of crop harvest, less impact on the environment, faster harvesting period and better quality of produced food under indoor farming practices. This technique helps growing greens without using any sun or soil. The vertical farming innovation uses smart light, smart nutrition, smart aeroponics and smart pest management. Aero Farms aims to transform the whole system of agriculture by building and making farms that are environmentally responsible. In short, they want to grow more crops in less space which can bring about a food revolution.

Considerations for vertical farming

One of the major issues currently facing under VF is that of limited scientific results related to yield potential, quality produce, energy efficiency and better utilization of resources of VF systems in order for their potential to be properly assessed. However, here are some key considerations for VF systems and their implications on its potential future success.

Crop choice

Crop choice in VF systems is currently limited, with most producers predominantly favoring small leafy vegetables and other salad leaves (Agrilyst, 2017). These crop types are well suited to cultivation in VF systems for a number of reasons. Their small size allows them to be grown in facilities such as stacked horizontal systems or cylindrical growth units where space, particularly in the vertical dimension, is at a premium. Small plant size also allows a higher number of plants and so potentially increased income per unit area horizontally. These crops show rapid growth and a short timeframe from germination to harvest, increasing the number of crops that can be produced in a season, further maximizing profitability and productivity. A rapid turnover of crops allows growers to better cope with problems such as crop loss due to disease or pest damage.

Economics

The start-up costs of VF systems are seen as a major constraint with site selection of high importance. While VF is generally discussed in relation to urban farming. This can take the advantage of land that is otherwise unsuited to unprotected cultivation and which otherwise may remain unused for food production, such as waste, depleted or heavy metal contaminated ground containing poor or unsuitable soil, or ex-industrial sites where the ground surface has been replaced with concrete or brick. The choice of rural versus urban location is an important one. For instance, it has been estimated that the installation of a rooftop glasshouse requires a minimum investment three times higher than that for a conventional ground-based glasshouse due to the required building adaptation (Brin et al., 2016).

Environmental effects

Vertical farming systems, reduced environmental impacts as compared to existing systems, for example by reducing transport requirements through locating production in urban areas. However, it has been calculated that the total greenhouse gas (GHG) emission of food systems, production accounts for 83 per cent, while transport only accounts for 11 per cent. In contrast, transport distances will be greatly reduced through urban localization and may lead to a net reduction in transport-associated energy requirements. Construction of VF facilities will also generate GHGs via building construction and energy use. However, the carbon footprint of the system (CO_2/kg lettuce) was five times higher than for conventional field-grown crops in the summer. Increased adoption of renewal energy infrastructure may therefore increase the viability and adoption of VF systems.

Energy requirements

As VF systems use glasshouse or controlled environment facilities, so expected use of energy may be higher than for field-grown crops. Maximizing efficiency in VF systems, which also frequently employ hydroponic culture, will therefore be key to their success, although it should be noted that soil-free cultivation can potentially increase yields up to 10 times compared to soil-based systems.

Conclusion and recommendations

VF is an emerging technology aiming to increase crop production per unit area of land in response to increasing pressure on agricultural production system. By utilizing protected horticulture systems such as glasshouses and controlled environment facilities in combination with multiple levels of growth surface and/or inclined production surfaces, VF is a technically demanding and expensive approach to crop production. Furthermore, VF is currently industry led, with a large number of independent start-up companies.

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