The Vertical Farming Response to the Agricultural Tropical Rainforest's Destruction

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Abstract: With economic development, agricultural expansion is gradually affecting the disruption of the tropical rainforest ecosystem. This article summarizes that agricultural development poses varying degrees of threats to the inorganic environment, organic environment, and climate change of tropical rainforests. To improve efficiency, reduce pollution, and protect the tropical rainforest ecosystem destroyed by the development of agriculture, this article proposes introducing vertical agriculture as a new agricultural production technology into tropical rainforest areas. At the same time, combined with vertical agricultural technology in terms of deforestation and pollution, the practical feasibility of replacing traditional agriculture with new technology is discussed. The technology has advantages, including occupying less land area, being clean and organic, saving water and energy, and being smart enough to achieve full control of crop planting efficiency. It proposes possible solutions for mitigating the adverse effects to provide a direction/reference for the healthy development of tropical rainforests. However, there are concerns about high costs, limited crop types, and fewer employment opportunities. Therefore, scientific researchers must increase the application range of this technology further and reduce costs.

1 INTRODUCTION

Currently, to develop the economy and improve the poverty situation, expansion of agriculture in the tropical rainforest is inevitable; however, this development brings destruction to the tropical rainforests, which would trigger serious consequences. The tropical rainforests are vital to the planet in many aspects. First, it is a colossal carbon pool that stores a large amount of carbon on the planet. Second, it could absorb a large amount of carbon dioxide and release oxygen, regulating and stabilizing the global climate. Third, it has the richest biodiversity on the earth. Therefore, the destruction of tropical rainforests will cause serious consequences, such as breaking the carbon-oxygen balance, exacerbating the greenhouse effect. It leads to soil erosion and desertification of tropical rainforests, leading to drought, high temperature, and wildfire. It also destroys the habitats of animals and plants, breaks the balance of the trophic cascade. Furthermore, the production methods of traditional agriculture are inefficient and have many impacts on the tropical rainforest environment. Therefore, it is imperative and urgent to develop an agricultural technology that can improve production efficiency while significantly reducing the impact on the environment. Be advised that papers in a technically unsuitable form will be returned for retyping. After returned the manuscript must be appropriately modified.

At present, there is a rare appropriate solution to the destruction of tropical rainforests to develop agriculture; a path that can lift local people out of poverty and protect the rainforest environment at the same time is still being explored. Some studies have proposed using sociology theory and government administrative means to interfere with rainforest agriculture. For example, after experiments with the theory of common-pool resources, it was found that when the property rights of the land are fully granted to the locals, deforestation can be effectively curbed (Alencar, 2015). However, the implementation of this measure is too much affected by human factors, and it has certain obstacles to the local economic development. Vertical farming is the practice of growing crops on vertically stacked levels, vertically inclined surfaces, or integrated with other structures, such as skyscrapers, warehouses, or shipping containers. The modern idea of vertical farming is to

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use indoor breeding technology and controlled environmental agricultural technology, in which all environmental causes can be controlled. Compared with traditional agriculture, vertical agriculture is energy-saving, water-saving, fertilizer, herbicides, and pesticides-free, pollution-free, clean, and organic, with much less floor space, and has high production efficiency. Therefore, it is of great help to the condition of deforestation problem. However, there is little relevant research yet, and vertical farming technology is still an immature technology, with the high cost and limited crops that can be grown, so the solution proposed in this article has a lot of research space.

This article summarizes the impact of agricultural development on tropical rainforests from the inorganic environment, organic environment, and climate change. In addition, this artic proposes possible solutions for mitigating the adverse effects and discusses the feasibility of this technology to provide a direction/reference for the healthy development of tropical rain forests.

2 IMPACT OF AGRICULTURE ON TROPICAL RAINFOREST

The tropical rainforests, also defined as lowland equatorial evergreen rainforests, are mainly distributed within 10 to 15 degrees on the two sides of the equator, located mainly in western and central Africa, southern and central America, and Malesian botanical subkingdom. These areas have a typical tropical rainforest climate, containing two sub-types: rainy equatorial climate, controlled by the equatorial low-pressure zone, and tropical oceanic climate controlled by the humid trade wind. The main characteristics of tropical rainforest climate include high precipitation (around 60mm); High temperature, and slight temperature variation. The sun shines directly on the ground twice a year, brings intense radiation and has little difference in the day and night length. Most of the tropical rainforests are distributes in developing countries. The local people live their lives depending on the exploitation and application of the rainforest resources, usually with agriculture, which includes cultivating crops suitable for growing in tropical rainforests and rearing animals such as cattle. Although agriculture could help reducing local poverty, it could also bring serious harm to the biophysical environment of tropical rainforests.

2.1 Impacts on the Inorganic Environment

First, conventional agriculture inevitably uses fertilizer to improve the survival rate of the young crops or increase the crops' harvest. The rapidly increased use of fertilizer in the rainforest areas leads to a concerning consequence. Usually, the crops can hardly absorb all the fertilizer; many nutrients would be lost to the environment in several ways. For example, if the rainwater flows through the ground of the field, it would take the nutrient into the physical environment of the rainforest (Edwards, 1970). When the nutrients enter the water body with the flow, it would have a chance to produce a phenomenon defined as eutrophication; The nutrient would harm the water quality by triggering dense blooms of phytoplankton, reducing the water's clarity, and producing a foul smell (D. Pivoto, P.D. Waquil, E. Talamini, C.P.S. Finocchio, V.F. Dalla Corte, G. de Vargas Mores). With the outbreak reproduction of phytoplankton, the water turns turbid and allows less light to penetrate through. Meanwhile, the unwanted phytoplankton consumes too much oxygen in the water, traps the heat beneath the water's surface, makes the water much warmer than clear ones, and changes the water's chemical composition. Eventually, eutrophication can cause considerable death of aquatic and nearby terrestrial lives; The fertilizer applied on the soil would decrease the pH level (H, 2005), disturb the soil enzyme activity and microbial population (Rodriguez, 2004), and increase heavy metal concentration (Chang, Chung, Tsai, 2020). In Turkey, research has shown that after consistently applying fertilizer for years to the tea plantation in the province of Rize, soil acidification appears and continuing to be more severe. 85% of the land has been observed to decrease to pH 4 or below and reach a critical level. Excessive fertilizer disrupts the soil's balance of nutrients and negatively affects the diversity of organisms like worms and soil mites (H, 2005).

Large-scale tropical rainforests have been through slash-and-burn clearing, a way of deforestation, to develop agriculture. Deforestation leads to soil erosion, which would change the tropical rainforest landscape, causing desertification and high temperature. For example, the destruction of primary forests of the Amazon region is rapid; In 2019, deforestation in Brazil, which contains more than half of the Amazon Forest, spiked by around 30% to almost 10,000 km2. By 2020, Brazil's rainforest has already shrunk around 15% compared to 1970, and 19% of Brazil's Amazon tropical rainforest's total area disappeared (Birkby, 2016). Thus, deforestation making large land areas vulnerable to erosion by wind, rain, and floods. In addition, because tree roots hold the soil together and retain water in the ecosystem, deforestation and subsequent erosion cycles will destroy habitats. Although agriculture replaces forests with crops, the foundations of non-native plants such as cotton and soybeans cannot keep rainforest soil in place. Once the plant cover disappears, there will be no roots to fix the soil during heavy tropical rains, and then wash away the topsoil and regenerate nutrients needed for future vegetation. As a result, the deforested rainforest soil becomes dry and lacks nutrients because there is no longer vegetation to keep water and nutrients in place. Furthermore, heavy rains have eroded the soil, and the eroded sediments can even change rivers. For instance, the Yangtze River in China has accumulated much sediment due to deforestation (Liu, 2007). However, the Yangtze River is not located in a tropical rainforest region, and the geomorphological principle remains the same. Another kind of landscape changing is desertification, a possible consequence of erosion caused by deforestation. When plant cover is lost to the critical level, erosion will take over (Jing, 2018), and the previously dense rainforest can turn into an arid desert.

2.2 Impacts on the Organic Environment

Agriculture expansion profoundly impacts the biological environment of tropical rainforests, from the most micro-ecological environment to the most macro-ecological environment.

Soil organisms are one of the most diverse biological communities on the planet (Baragwanath, 2020), and it is the same in the tropical rainforest. Bacteria, fungi, actinomycetes, and algae constitute the soil microbial community. They carry out oxidation, nitrification, ammonification, nitrogen fixation, sulfidation, and other processes in the soil to promote the decomposition of organic matters in the soil and the conversion of nutrients. Thus, the soil microbial community is the most fundamental part of the ecological cycle. However, overusing fertilizer causes heavy metal concentration in the soil, which has adverse effects on the activity and the amount of soil microbial community. Heavy metal ions can inhibit micro-organisms; Various metabolisms denature proteins, inhibit cell division or make cells; The membrane ruptures change the specificity of the enzyme, destroys cell function and the DNA structure (Benke, 2017). Thus, the activities and population size of soil microbial communities of the tropical rainforests were reduced and destroyed. This phenomenon would directly impact the upper niches of biology.

Applying herbicides and pesticides to enhance the crops' efficiency in conventional intensive agricultural production activities is very common. However, herbicides and pesticides have intense negative impacts on the organisms in the tropical rainforests. Pesticides and herbicides may affect micro-organisms populations, directly or indirectly of soil invertebrates by limiting their living essentials (L. Gibson, T.M. Lee, L.P. Koh, B.W. Brook, T.A. Gardner, J. Barlow, C.A. Peres, C.J.A. Bradshaw, W.F. Laurance, T.E. Lovejoy, N.S. Sodhi), affect plants and animals at different nutritional levels. For example, there are numerous insects, spiders, ticks, earthworms, nematodes, and other invertebrates in tropical nature. At the same time, pesticides and herbicides have significant direct elimination effects on these animals' growth, reproduction, and survival. Thus, the loss of these arthropods would lead to the loss of upper predators, like birds and frogs; In the same way, the loss of secondary consumers would cause the loss of top predators. Therefore, pesticides and herbicides will change the species composition and structure of tropical rainforest organism communities and reduce the tropical rainforest biodiversity (L.R. Vargas Zeppetello, L.A. Parsons, J.T. Spector, R.L. Naylor, D.S. Battisti, Y.J. Masuda, N.H. Wolff).

Studies have shown that deforestation has adverse effects on tropical biodiversity and primary forests are no substitute for maintaining tropical nature biodiversity (SharathKumar, Heuvelink, Marcelis, 2020). Nonetheless, agricultural deforestation, for example, the slash-and-burn clearing and the cut-down clearing, also changes the ecological environment of the tropical rainforests by destroying the habitat, breaking the food web, and reducing biodiversity. For instance, only 40% of the forest-based plant and insect species could also be found in the tropical rainforest conventional cocoa plantation (Chislock, Doster, Zitomer, Wilson, 2013). With the significant area loss of habitat, a large scale of organisms is suffering local extinction. Numerous species, even some top predators, for example, the tiger, which used to spread widely over Asia, have been observed gradually functional extinct. Tigers have only been found in just 7% of their original geographical distribution range (P. Shukla, J. Skea, 2019).

2.3 Impacts on Global Climate

A large scale of deforestation on tropical rainforests would directly cause the phenomenon of global warming. In 2019, the IPCC issued a report about climate and land, pointing out the causal relations between tropical rainforests and global cycles of energy, water, and carbon. This report indicates that tropical deforestation is one of the climate change issues threatening the most prominent land-based carbon pools on earth (Savci, 2012). For example, from 2003 to 2018, deforestation in Southeast Asia reached 11% of the total area of tropical rainforests. Furthermore, studies have shown that 65% of areas where the temperature has risen by 5 °C have experienced deforestation. The same thing happens in Amazon; 5 ◦C has risen, while deforestation is just 4% of the total rainforest area. Study shows that this warming amount is nearly equal to around a hundred years of greenhouse gas emission induced climate change (Gbarakoro, 2013).

3 VERTICAL FARMING

Vertical farming is a plantation way to grow considerably more crops in the same area than traditional, horizontal farming. The types of vertical farms model have different shapes and sizes, from simple two-story or wall-mounted systems to large warehouses with several stories high. Vertical farms can be divided into hydroponics, air cultivation, or fish and vegetable symbiosis to provide nutrients for plants. The advantages of this technology are abundant. Multiple combinations of AI, artificial light, sensor monitoring, climate control systems, and other facilities and tools make agriculture controllable. Crops are stacked in layers or rows, sometimes up to 20 to 30 feet tall. All vertical farms use LED lights to create a specific lighting scheme for each plant, thereby providing green plants with the precise spectrum, intensity, and frequency required for photosynthesis. Several key factors determine the feasibility of a vertical farm. First, the physical layout: Indoor farming aims to maximize the output efficiency per square meter, which is the source of the vertical tower structure. Second, the lighting: Lighting optimization for crop growth in vertical agriculture usually involves growing lights and natural light. Professional technology such as rotating beds improves the efficiency of the light source and can meet the needs of different crops. There are three different indoor agricultural systems models: hydroponics, aeroponic, and fish and vegetable symbiosis. In hydroponics, crops are grown in nutrient-rich water basins, and water is recycled, increasing efficiency and reducing water consumption. In addition, hydroponic agriculture is scalable in scale and cost, which is very suitable for farmers' production goals and needs. It includes drip irrigation, deep water cultivation, ebb and flow, nutrient film technology, and a wick system. Aeroponic agriculture uses regular timers (no soil, sunlight, or water) to frequently spray crops with nutrient-based mist. Then, Aeroponics delivers nutrients directly to plant roots to save water and reduce labor-intensive. Scalability is another great advantage of this method, as crops can be harvested easily without the need for soil. Fish and vegetable symbiosis is a closed-loop food production system; aquaponics is the practice of cultivating fish and plants simultaneously. Fish provide nutrients and beneficial bacteria to plants, and plants filter water for fish. Thus, the fish and vegetable symbiosis creates a high-yield and balanced ecosystem with many benefits, including water-saving methods. As is shown in Fig.1, the vertical farms work in a clean, energy-saving, orderly and smart environment. LED lights to provide suitable light while the water supplements and nutrients solutions are under culture beds, and air conditioners maintain the air cycle system in the vertical farm. All these factors are controlled precisely by the AI system, and solar panels and storage batteries provide electric energy.

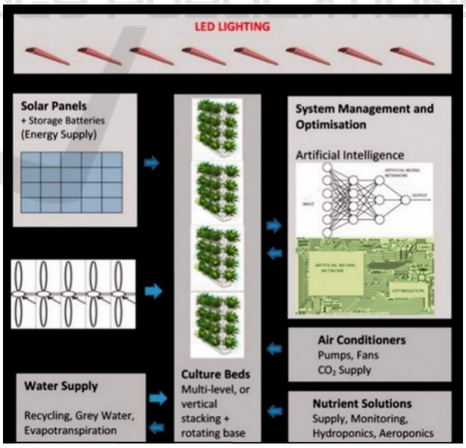

Figure 1: The mechanism of vertical farming (W. Abtew, A.M. Melesse, 2016).

First, since this vertical farming requires the accurate control of light, water, temperature, and humidity, this technology was combined with smart farming in AI to realize efficient, eco-friendly production. Researchers use artificial intelligence to coordinate the whole vertical farming lab and simulate the natural growing environment of the crops—smart farming, including incorporating communication technologies and information. The smart farming producing system uses communication technologies, the internet of things, cloud computing technologies, robots, machinery, equipment, and sensors (Laurance, Sayer, Cassman, 2014). Vertical farming could be a solution to tropical agricultural deforestation. Second, it allows less land use since it is skyward; Only a tiny amount of land would be required for growing the crops. This means slash-and-burn deforestation is unnecessary. Third, vertical farming is eco-friendly and allows a reduction or total abandonment of chemical pesticides and herbicides (Z. Atafar); workers need to be disinfected before working, which means less harmful bacteria, plant viruses, and pests would have a chance to go into the lab. Moreover, since vertical farming is also soilless cultivation; the culture medium is organic and eco-friendly, such as coconut shells, the nutrient supply of crops comes from the environmentally friendly organic nutrient solution. Some soil-borne crop diseases, insect pests, or weeds do not happen in the lab, which means chemicals like pesticides and herbicides no longer need to be applied. Thus, environmental contamination, for example, the waterbody and the soil contamination caused by fertilizer, pesticides, and herbicides mentioned above, would not appear. Last, the energy and resource consumption of vertical farming is small. The power that vertical farming labs use could be solar energy, considered as clean and safe energy, and reduce carbon emissions significantly. Highly efficient Light-Emitting Diodes are used in most vertical farms, and only the red and blue light bulbs are needed, the most beneficial for optimizing plant growth, ad eliminating other light waves helps reduce energy costs by 15% (Z. Atafar). The water applied in the vertical farm is also recyclable; even the humidity in the atmosphere in the lab would be collected and reused, which means the eutrophication is not going to happen in the natural environment. Fig. 2 is the plant phenotype with desirable attributes for vertical farming. Vertical farming provides high-quality crop productions, while the processes of growing the crops are high efficiency.

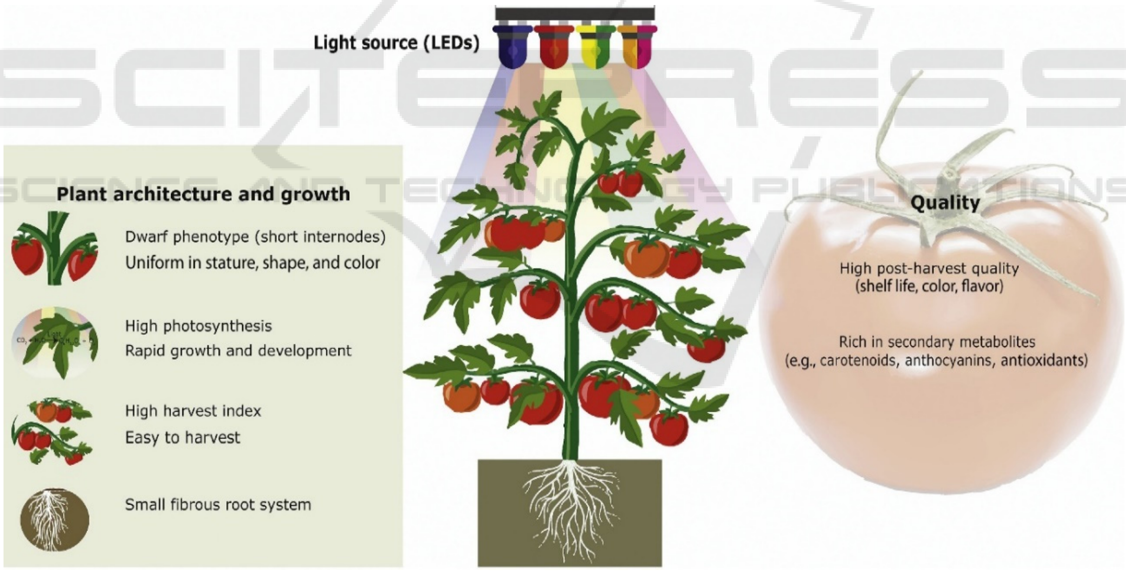

Figure 2: Ideal plant phenotype with desirable attributes for vertical farming.

In contrast, vertical agriculture also has its limitations. Initially, vertical farming requires considerable financial investment, such as patents, researches, developments, equipment, and AI technology expenses. However, tropical rainforest agricultural deforestation usually happens in developing countries, and less capital could be applied to the vertical technology. Furthermore, since vertical farms widely use AI technology, practices like breeding, watering, temperature, and humidity control can all be coordinated by computers and operated by robots, fewer jobs could be offered to the poverty. Thus, developing vertical farms is counter to the original intention of tropical rainforest agriculture. The needs, which are tackling poverty and livelihood issues, have not been met, so the problem cannot be solved unless the process of vertical farming replacing the traditional horizontal farming in tropical rainforests becomes an international cooperating project. Furthermore, in vertical farming projects, there is necessary to provide services with a supply of skilled labor or scientific resources workers with a university education certification. However, in most tropical agriculture deforestation areas, people have fewer chances and financial aids to accept higher education. Third, vertical farming technology has focused on some specific species of crops. Current models of vertically grown crops are high value, fast growth, small area, and fast turnover species. For example, leafy greens are trendy as a vertical farming crop because they provide a premium profit margin (Abtew, Melesse, 2016), such as lettuce, basil, and a few "salad" crops. Fourth, slow-growing vegetables and grains are not so profitable that commercial crops have not been introduced into the vertical farming system (Z. Atafar). However, in tropical rainforest agriculture, the crops grown in tropical areas are usually banana, cocoa, rice, oil palm, etc.; all of these crops are still have not been studied as vertical farming growing crops.

4 CONCLUSIONS

Most tropical rainforests are distributed in developing countries, which means that the developing economy by cutting down tropical rainforests and expanding agriculture is inevitable. To realize the conservative practices of the tropical rainforest, finding a new method of developing agriculture is becoming urgent. This article discusses the impact of agricultural development on tropical rain forests and the global climate, such as eutrophication of tropical rain forests, soil heavy metal pollution, and reduction of biodiversity. Excessive carbon emissions caused by deforestation and the development of agriculture will destroy the global carbon and oxygen balance, intensify the greenhouse effect and affect the global climate. This article proposes that vertical agriculture may be one of the solutions to this problem. Vertical farming saves most of the water, land, and energy in growing crops, and it is also clean and organic. Meanwhile, it allows less environmental contamination and carbon emission. However, the technology currently has the following problems: the cost is higher than traditional agriculture, the crops grown are limited to salad vegetables, and there are no growing tropical crops. Furthermore, with artificial intelligence technology and robots in vertical farms, locals rarely have a working chance. Although there are some concerns, there is much space for more research in this area.

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