International Journal of Scientific Research & Engineering Trends
Volume 10, Issue 2, Mar-Apr-2024, ISSN (Online): 2395-566X

Vertical Farming: An energy effective form of Agriculture

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Abstract- The title of our project is Vertical Farming. Compared to traditional farming where the crops are grown in open flat land which uses a lot of space, vertical farming utilizes vertical frames for growing plants in a vertical columnal manner. The crops are grown in closed spaces where all the parameters and conditions of the plant are monitored and controlled. Using vertical farming has several benefits. The major benefit is reduced consumption of water and reduced amount of space required. There are mainly three types of vertical farming: - Hydroponics, aquaponic and aeroponics. But there are many challenges such as the high startup cost and the vast amount of energy required. But we have made our own innovative design modifications and a separate system to counter the problems.

Index Terms- land, vertical, closed, parameters, water, space, startup, energy, innovative, problems

I. INTRODUCTION

The topic of out project is vertical farming. In traditional farming, crops are grown on open lands which consumes a vast amount of space. Also, traditional farms use up a lot of water and are also affected by fluctuating weather conditions, insect infestations, animal interference, etc. But in vertical farming, the crops are grown on vertical panels which are then stacked on top of each other. What this does is minimize the usage of land. Also, the water is continuously circulated between the plants. Due to this, the usage of water is reduced as unlike traditional farms, the water does not get absorbed into the ground or evaporated. Also, vertical farms are a closed system meaning that the farm is closed and secured from all sides. This prevents problems such as weather and insect interference, animal attacks, etc.

As of now, there are three main types of vertical farming, hydroponics, aquaponics and aeroponics. But the most efficient are hydroponics and aeroponics. In hydroponic method, the plants are submerged in the water itself. The water itself contains all the nutrients which the plants can absorb as and when required. This water is continuously circulated between the plants in order to minimize wastage of water and to make sure that nutrients can be continuously supplied to the plants. In aquaponic system, the water is first supplied to the fishes in another tank. Then, the dirty water from the fish tank is purified for solid waste and then, the nutrient rich water is supplied to the plants. This water is again then cleaned and supplied to the plants. In aeroponic system, the plants are arranged in a tower like structure where the roots of the plant are arranged in a systematic way one on top of each other and then water is sprayed directly on the roots. Then, the excess water can easily drain to the bottom and then cycled again.

The main challenge is the initial startup cost and the huge amount of energy required to provide the lighting to the plants, to power the pumps, etc. But we have created a solution for it based on smart solar panels.

II. LITERATURE SURVEY

1. "Vertical Farming: The Only Way Is Up?" by Dr. Thijs Van Gerrewey, Nico Boon, Danny Gleen
In this paper we go through the introductory part of closed loop hydroponic system where we learn how a hydroponic solution work. This system capture and recirculate the nutrient solution for an extended period without the need to evacuate the nutrient solution. Recirculation drastically improves water-use efficiency and reduces fertilizers and pesticides emitted to the environment compared to open-loop agricultural systems. The historical overview outlines the trajectory from design innovation to the current emphasis on environmental, economic, social, and political aspects of vertical farming.

2."Opportunities and Challenges in Sustainability of Vertical Farming: A Review "
Global food demand is increasing, putting pressure on arable land. Vertical farming (VF) is proposed as a solution, utilizing high-rise buildings and advanced technologies to enhance

food production. VF involves controlled environmental conditions and hydroponics for fast and planned crop growth. Despite VF being a relatively new concept, it integrates engineering and natural sciences, offering multiple applications in society and the environment. While technical challenges exist, VF is gaining momentum globally, with various countries implementing and exploring its feasibility for sustainable urban food production.

3. "Vertical Farming" By Jeff Birk NCAT Smart Growth Specialist

Vertical farming addresses the challenge of limited agricultural space by utilizing abandoned warehouses, environmentally damaged lands, and shipping containers for controlled indoor cultivation. This innovative approach involves stacking plant layers in multi-story structures. In the United States, commercial-scale vertical farms gained serious attention around 2015, with various sizes and shapes emerging. Three soil-free systems—hydroponics, aeroponics, and aquaponics—are used, with hydroponics being the predominant method. NASA pioneered aeroponics, a highly efficient technique using air/mist environments, attracting significant interest for its water-saving potential.

4. "Farming up the city: The rise of urban vertical farms" by Dickson Despommier

Vertical farming, explored in Jeff Birkby's ATTRA article, utilizes abandoned warehouses, damaged lands, and shipping containers for controlled indoor crop cultivation.
Commercial-scale vertical farms gained attention in the United States around 2015, with a growing interest in this innovative farming technology.

Controlled environment agriculture (CEA) has evolved, aided by spectrum-specific LED grow lights and computer-assisted systems, offering precise control over conditions for optimal crop growth.

CEA provides advantages over traditional soil-based agriculture, maximizing yields per square foot and enabling multiple harvests per year, particularly notable in hydroponically grown leafy greens.

The article highlights the potential of vertical farming to address food production challenges in densely settled regions and its commercial viability with advancements in technology.

5. "Vertical Farming: The Only Way Is Up?"

Anticipating a global population of 9 billion with 70% residing in urban areas by 2050, the strain on food resources prompts consideration of vertical farming.

The paper aims to assess vertical farming's feasibility through a socio-technical, mixed-methods approach, examining energy requirements, carbon footprint, and stakeholder perceptions. Key aspects include constructing an energy model to evaluate renewable energy viability, quantifying carbon emissions from vertically grown produce compared to conventional methods, and exploring stakeholder views.

Findings suggest that vertical farming can be a sustainable food supply tool, contingent on location and design considerations.

The study identifies areas for future research, emphasizing the nuanced role of vertical farming in addressing urban food challenges.

III. METHODOLOGY/EXPERIMENTAL

1. Components

Light Dependent Resistor (LDR)

LDR is a type of photoresistor that exhibits a change in resistance based on the intensity of light falling on its surface. LDRs operate on the principle of the photoconductive effect, where the resistance decreases as the light intensity increases.

Arduino Uno

The Arduino Uno is a popular open-source microcontroller board designed for easy prototyping of electronics.

Servo Motor

A servo motor is a rotary actuator that allows for precise control of angular position, velocity, and acceleration.

Servo motors operate based on a closed-loop control system, where they receive feedback about their actual position and adjust their movement to reach a desired position.

Hydroponic Solution - Hydroponic Solution

The hydroponic solution refers to the nutrient-rich water mixture used to provide essential elements and minerals directly to plant roots.

The hydroponic solution contains a carefully balanced mix of essential nutrients required for plant growth. These nutrients include macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S)

Resistor

A resistor is a passive two-terminal electronic component that restricts or limits the flow of electric current.

Solar Panel

A solar panel, also known as a photovoltaic (PV) panel, is a device that converts sunlight into electrical energy through the photovoltaic effect.

Solar panels are made up of individual photovoltaic cells, typically composed of semiconductor materials such as

silicon. These cells convert sunlight into direct current (DC) electricity.

Breadboard
A breadboard is a fundamental tool used in electronics for prototyping and testing circuits without soldering.

Other Components
Cardboard, tubes, multi section tray, tub, pump, etc.

2. Software Used
For our project, the software that we have used is Arduino ide. Using this software enables us to program the Arduino uno which plays a major role in our project.

3. Design
We have created a simulation of how our project would look when it is scaled to a real life version. First, we have created a model of a vertical farm using a plastic multi-section tray. The tray contains some grass which simulates the crop that we are growing.

Then we have attached a pump which simulates the way through which we will provide water which will fall to a tray at the bottom which then can be recirculated through the pump.

Then we have simulated a brewery using a cardboard and two plastic bottles. The idea is that we can start a brewery next to the vertical farm itself. Then, the co2 that is produced in the brewery can be supplied to the vertical farm directly as plants require huge amounts of co2 for photosynthesis.

Then is our innovative system. In this innovative system, what we have done is created an open tower type structure with cardboard. This will simulate a real-life building which will be open with no walls between floors.

Then, multiple solar panels can be inserted in each floor which will have a system that can turn the solar panel to the direction of the sunlight. This has been simulated with the help of an Arduino system where we have used ldrs to detect light and then turn the solar panel to the direction of the light using the ldrs.

The circuit that we are using to simulate the smart solar panels between the floors consists of two ldrs which will sense incoming sunlight.

Then, the value of the two ldrs will be compared. If the difference in the values of the ldrs is less then ten(our threshold difference), then the solar panels will not move. But, if the difference is greater than ten, then the solar panel will move in the direction of the source of light which is opposite to the side of the ldr.

4. Circuit Diagram and Code

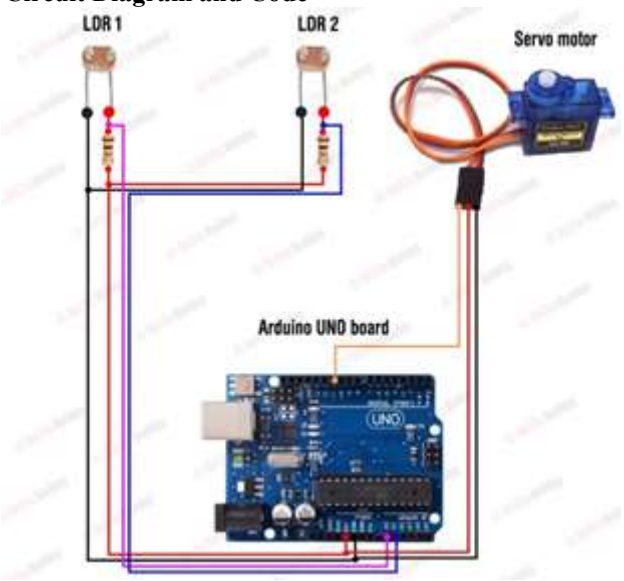

Figure 1: Circuit diagram

Code –

```
//Include the servo motor library
#include <Servo.h>
//Define the LDR sensor pins
#define LDR1 A0
#define LDR2 A1
//Define the error value. You can change it as you like
#define error 10
//Starting point of the servo motor
int Spoint =  90;
//Create an object for the servo motor
Servo servo;

void setup() {
//Include servo motor PWM pin
  servo.attach(11);
//Set the starting point of the servo
  servo.write(Spoint);
  delay(1000);
}

void loop() {
//Get the LDR sensor value
  int ldr1 = analogRead(LDR1);
//Get the LDR sensor value
  int ldr2 = analogRead(LDR2);

//Get the difference of these values
  int value1 = abs(ldr1 - ldr2);
  int value2 = abs(ldr2 - ldr1);

//Check these values using a IF condition
  if ((value1 <= error) || (value2 <= error)) {
```

```
  } else {
    if (ldr1 > ldr2) {
      Spoint = --Spoint;
    }
    if (ldr1 < ldr2) {
      Spoint = ++Spoint;
    }
  }
//Write values on the servo motor
  servo.write(Spoint);
  delay(80);
```

IV. RESULTS AND DISCUSSIONS

In our project, we have used the brewery model to simulate any co2 producing factory as if we build factories like these besides the vertical farm itself, then we can supply the co2 directly to the farm for the plants to use it as food.

There are many factories today that produce huge amounts of co2 such as breweries, chemical factories, etc. Generally, these gases are released into the environment which causes a lot of harm. But, if these factories are built next to the vertical farm itself to reduce the transportation distance, then the co2 can be directly supplied to the plants in the vertical farm thereby reducing harm to the environment.

Based on previous research, generally an acre of crops grown through vertical farms require about 5.4 acres of solar panels for producing the energy required. But this defeats the original purpose of the vertical farm which is to reduce the space required by the farms.

But using our innovative solution of a solar tower, we can build a tower similar to the vertical farm with each floor containing solar panels to maximize production of energy. This is done as the solar panels can detect the direction of the sunlight and then, lean towards the direction of the sun.

Helpful Hints

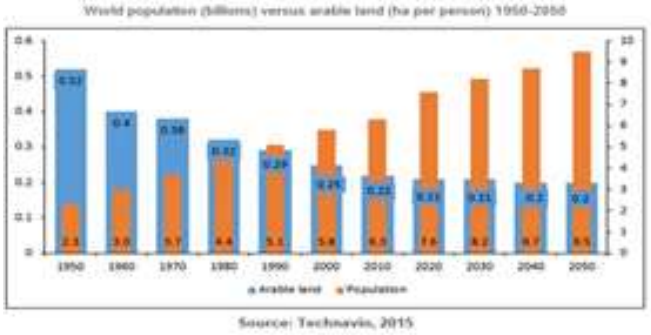

Figure 2: Reduction of land and increase in population over period of 11 decades.

	Actual Yield Open Field (kg/m^2)	Actual Yield Protected Field (kg/m^2)	Potential Yield Indoor Farm (kg/m^2)	Potential Yield Vertical Farm (kg/m^2)
Tomato	6.50	15.00	22.10	3562
Potato	6.00	7.00	32.40	3312
Green Pepper	3.51	5.50	15.40	2471
Carrot	2.51	3.00	4.80	871
Lettuce	4.50	5.25	6.75	3191
Cabbage	5.50	6.51	7.15	1183

[1] Calculated from source data: [10].

V. FUTURE SCOPE

As we all know that population is increasing day by day and that population requires land to live and survive so using this purpose we can save the land and also we can grow many plants in small area.

We can apply this idea at home level also, like we can create a small farm in our garden having vertical components in which we can plant seeds and grow plants. The main scope is we have used IOT based system so using that we can handle the process of watering of plants on our device which can be used easily.

1. Technological Advancements

- Continued advancements in technology, such as improvements in LED lighting, automation, , will enhance the efficiency and productivity of vertical farming systems.
- Integration of sensor technologies, IOT based system and data analytics will enable more precise monitoring and control of environmental conditions, leading to optimized crop growth.

2. Crop Diversity

- Ongoing research is focused on expanding the range of crops that can be successfully cultivated in vertical farming systems. Efforts are being made to grow larger and more diverse crops, including fruits and vegetables, to increase the variety of produce available.

3. Vertical Farms in Urban Planning

- The integration of vertical farms into urban planning and architecture holds potential for transforming cities into more sustainable and self-sufficient environments.
- Urban vertical farms could reduce the need for long-distance transportation of food, contributing to lower carbon emissions and increased food security in densely populated areas.

V. CONCLUSION

As of now, due to the high startup costs and the limited types of crops available, the vertical farm is not very effective. Also,

due to the huge energy requirements, the price of common products such as bread is very high. But as research goes on and these problems are solved, we hope to include these farms everywhere including urban areas. Some of the new technologies that are being used are zapping of seeds and plants. When seeds are zapped before germination, they have a higher probability of germination and they do so faster. Also, it has been observed that when tomato plants were zapped, their yield increased by 40 %. We hope to use these technologies to further increase the efficiency of our vertical farms.

Acknowledgment
We`d like to thank our guide Prof. Rajesh J. Dhake for helping us with this project as well as our college Vishwakarma Institute of Technology for providing us with this wonderful opportunity to create this project.

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