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(RESEARCH ARTICLE)

Aerogarden: An aeroponics innovation project linking artificial intelligence and sustainability

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Abstract

Every year, 10.8 to 19.1 billion tonnes of CO2 are emitted through food exports, which accounts for roughly 21% - 37% of the world's global total emissions. In the urge to expand businesses and ensure availability of all crops throughout the year, the quality of air is being compromised. The demand for crops rises in tandem with population growth and improvements in human well-being. In addition, most of these exported crops lose their nutritional value due to the unhealthy exposure of preservatives and other farming chemicals. There are multiple factors involved in crop production: land, labour, transportation, storage etc. Aeroponics is a relatively new farming system that eradicates numerous problems by using less land and water and requiring minimal labour and nutrients. The aim of this project is to convert the aeroponic farming unit into a 100% carbon-neutral, self-reliant unit called Aerogarden by integrating modern technology like Artificial Intelligence (AI). Every household having an Aerogarden unit can access fresh organic vegetables and microgreens that actually retain their nutritional value. By achieving this goal, non-agricultural nations' dependence on food imports will lessen, which will ultimately result in a reduction in the sector's carbon footprint. By giving people a way to directly support the international movement, the project also aims to support the UN's initiative to achieve the 17 Sustainable Development Goals.

Keywords: Aeroponics; Aerogarden; Carbon-Neutral; AI integration; Sustainability

1. Introduction

Aim

This project's primary goals can be broadly divided into three sections:

- To produce high-quality crops with minimal input. Aeroponics is a very efficient way to grow plants, using up to 95% less water and 98% less land than traditional agriculture. This makes it an ideal solution for growing food in areas with limited resources. (Keller, 2020)[1]
- To develop new aeroponic technologies and systems. Aeroponics is a relatively new technology, and there is still much room for innovation. Aeroponics projects such as Aerogarden can help to develop new and more efficient ways to grow plants using aeroponics. (Keller, 2020)[1]
- To educate the public about aeroponics and its benefits. Aeroponics is a sustainable and efficient way to grow food, but it is still relatively unknown to many people. Aeroponics projects can help to raise awareness of aeroponics and its potential benefits for society.

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1.1. Scientific concepts

1.1.1. Artificial Intelligence

Artificial intelligence, or AI, is technology that enables computers and machines to simulate human intelligence and problem-solving capabilities. (IBM, 2023)[2]

1.1.2. Machine Learning

Machine learning (ML) is a branch of artificial intelligence (AI) and computer science that focuses on the using data and algorithms to enable AI to imitate the way that humans learn, gradually improving its accuracy. (IBM, 2021)[3]

1.1.3. Aeroponics

Aeroponics is a method of growing plants in a soil-free environment where the plant roots are suspended in air and are misted with a nutrient-rich water solution. They typically use pumps, timers, and spray nozzles to deliver a highly oxygenated mist of water and nutrients to the plant roots. (Garzón et al., 2023)[4]

1.2. Design

The basic idea of the project is to equip existing models with technology to ease out the cultivation process. The unit features a standard, 20-pot aeroponics tower pre-equipped with a submersible water pump. External modifications include a pH meter (to measure salinity), a TDS meter (to check the total dissolved solids), light strips for artificial lighting and a master circuit connecting the sensors. In its advanced stages, the project also aims to make the unit solar powered to make the unit 100% carbon neutral.

1.3. Advantages

- Uses 95% less water and up to 98% less land.
- Does not use soil and uses alternate mediums like coconut husks to grow.
- Roots are freely suspended in the air to acquire more oxygen than conventional farming methods.
- Use of harmful chemicals like pesticides and insecticides is minimized to a large extent.
- Crops and microgreens grow faster and yield fresher produce.
- Profitable for agriculturalists, can be grown at home on a small scale.
- Increases the possibility of local cultivation and thus reduces carbon emissions.
- Solves problems of unemployment in the primary sector in developing countries.
- Farming experts claim this method is the ‘future of farming’.
- Generates awareness among the common people about the need to grow basic crops at home.

1.4. Drawbacks

Despite its advantages, aeroponics also faces some challenges. One challenge is the initial cost of setting up an aeroponics system. Aeroponics systems can be more expensive to set up than traditional agriculture systems. However, the long-term savings in water and nutrient costs can offset the initial investment.

Another challenge is the complexity of aeroponics systems. Aeroponics systems require careful monitoring and maintenance to ensure that the plants are receiving the right amount of nutrients and water. If the system is not properly maintained, the plants can quickly die.

Lastly, it requires constant power supply for the water pump and lights to operate. This can be resolved by using solar energy, making it 100% carbon neutral. (Brandon & Makisig, 2024)[5]

2. Methods

2.1. Why Aeroponics?

Methods / Parameters	Aeroponics	Hydroponics	Aquaponics
Feasibility	Can cultivate large number of crops, produces the highest yield and nutrition.	A variety of crops can be grown using this method and can be commercial.	Similar yield as compared to hydroponics.
Cost of Production and Maintenance	Initial setup of the model is high, but its maintenance is low due to low requirements of water and energy.	Initial setup of hydroponics is low, but its maintenance may be a problem due to its high requirements of water.	Its setup and maintenance are the highest.
Speed of Production	Faster than traditional farming and hydroponics.	Faster than traditional farming.	Faster than traditional farming and also provides a habitable environment for aquatic fauna.
Difficulty	Difficult to set up for beginners as it uses complex technologies.	Easiest to set up and is beginner friendly.	Moderately difficult, is easy to use after initial setup.

Figure 1 Method Comparison

2.2. The App: Aerogarden

2.2.1. Salient Features

- *Wi-Fi Connectivity*

Aerogarden uses Wi-Fi connectivity (on the Samsung Smart Things Domain) to connect to a compatible device (smart plug outlet). Users can choose any discoverable device to connect and control. If they opt for manual farming, they can use the ON and OFF buttons to control the unit.

- *Profile creation using Email and Firebase*

Users can Sign Up or In using email and secure the same with a password that is verified. The app has a database on Firebase and is currently usable only on android. After Signing Up or In, a user may connect to a device and begin growing their microgreens.

- *Using AI to determine materials needed and control the model*

    - Dashboard

The dashboard has a large prompt that says, 'Choose your crop', indicating users to pick a crop to continue the farming process. Upon some research, it has been found that greens and vegetables like lettuce, kale and tomato are easily grown on vertical gardens, making it a top choice for beginners to cultivate. The trial version of the app shall test out automated farming of the 3 aforementioned crops.

    - Auto/Manual Farming

Upon clicking on any of the 3 mentioned crops, the app shall direct the user to a screen where they decide if they want to cultivate the crop automatically or on their own.

    - Manual Farming

For those opting to cultivating a crop on their own, the required information on tools needed will be displayed along with a page filled with user guides to aid the user with their farming. As mentioned earlier, the manual controls can be operated using the ON and OFF buttons. The user may always have the option to switch to automatic mode later on.

    - Auto Farming

Users opting to farm automatically using AI would be presented with a similar screen as the manual users, displaying the required materials for the crop chosen. Once they've confirmed their inventory, the app shall proceed to operate the unit with the required amount of light and water. Like manual users, auto farming users will also have the chance to terminate the process or switch to manual mode. The list of user guides can still be accessible to auto farming users under a designated 'user manual' section.

2.2.2. Details That Can Be Monitored

- User Profile

Information such as User Email and password are verified and stored securely in the app's database. Users may also delete their accounts at any given time.

- Crop Data

This shows various data of the crop currently being cultivated (only monitored if on auto mode). Some of the data stored and monitored are:

    - Duration of farming a certain crop
    - Light used (quantity)
    - Water used (quantity)

- Data driven decision making

AI analyzes data from multiple sources to provide actionable insights to growers, helping them make informed decisions about crop management strategies.

- Crop Specific recommendations

AI-powered platforms can provide crop-specific recommendations on nutrient dosages, environmental conditions, and growth strategies based on real-time data and historical trends.

2.2.3. Parameters That Can Be Controlled

- Wi-Fi connectivity

The application uses Wi-Fi to connect and disconnect a device of their choice. Users opting for manual farming may control their device using the ON and OFF buttons.

- User Profile details

Users can edit some details like email and password, or even delete their account. In the future versions of this app, additional features like username and profile pictures may also be added.

- Auto farming/switch to manual

When a user clicks on 'auto farming', they are presented with 3 options of crops to farm (in the 1st version of this app): Lettuce, Tomato and Spinach. Upon choosing a crop, they are further presented with data such as est. duration, water required, energy consumed, CO2 saved by choosing this alternative, light required etc. Once the user is ready to farm with the required tools and seeds, they may click on 'start' and the automated process begins.

A user manual will be provided in the app to educate the users on aeroponics. If they wish to switch to manual farming, they may do so by clicking a simple button. Similarly, if they wish to terminate the process, they must follow a similar procedure.

- Automated Nutrient Management (advanced stage):

AI can analyze real-time data from sensors measuring nutrient levels in the aeroponic system. It can then adjust nutrient dosages based on plant needs, optimizing growth conditions and reducing waste.

Sensors to be used: pH scale detector, electrical conductivity tester.

- Pest and disease detection (advanced stage)

AI-powered image recognition and machine learning models can identify early signs of pests or diseases by analyzing images of plants. Timely detection enables prompt intervention and minimizes crop damage. The cameras may operate 2-3 times a day to ensure the crops are pest free. Each plant socket will have special codes for users to detect which part of the unit has been infected/contaminated.

- Optimized lighting management (advanced stage)

AI algorithms can determine the ideal light spectrum and intensity for different growth stages of plants. This ensures efficient use of artificial lighting and maximizes photosynthesis. The app will also be fed with predetermined information on light requirements per day for a given crop.

- End Goal (of the app)

The app's main goal is to aid users, both professionals and beginners, in controlling an aeroponic system. It is a relatively new form of farming that involves minute amounts of technology. The app takes it a step further by automating the entire process. It can teach users how to farm microgreens by initially automating the process. The app also includes a guide filled with useful information that a user can use if they are in need of assistance. This simplified app will help users understand the many advantages of aeroponics. It is one of several methods for educating the public about the Aeroponics process.

2.3. App Preview

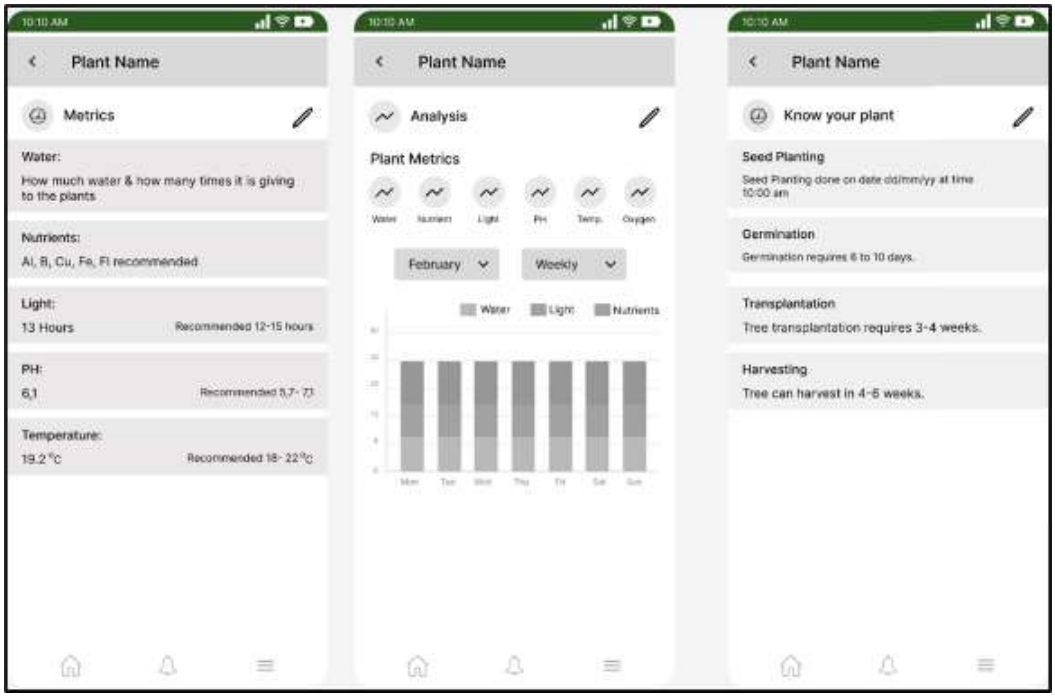

Figure 2 Details provided to a user

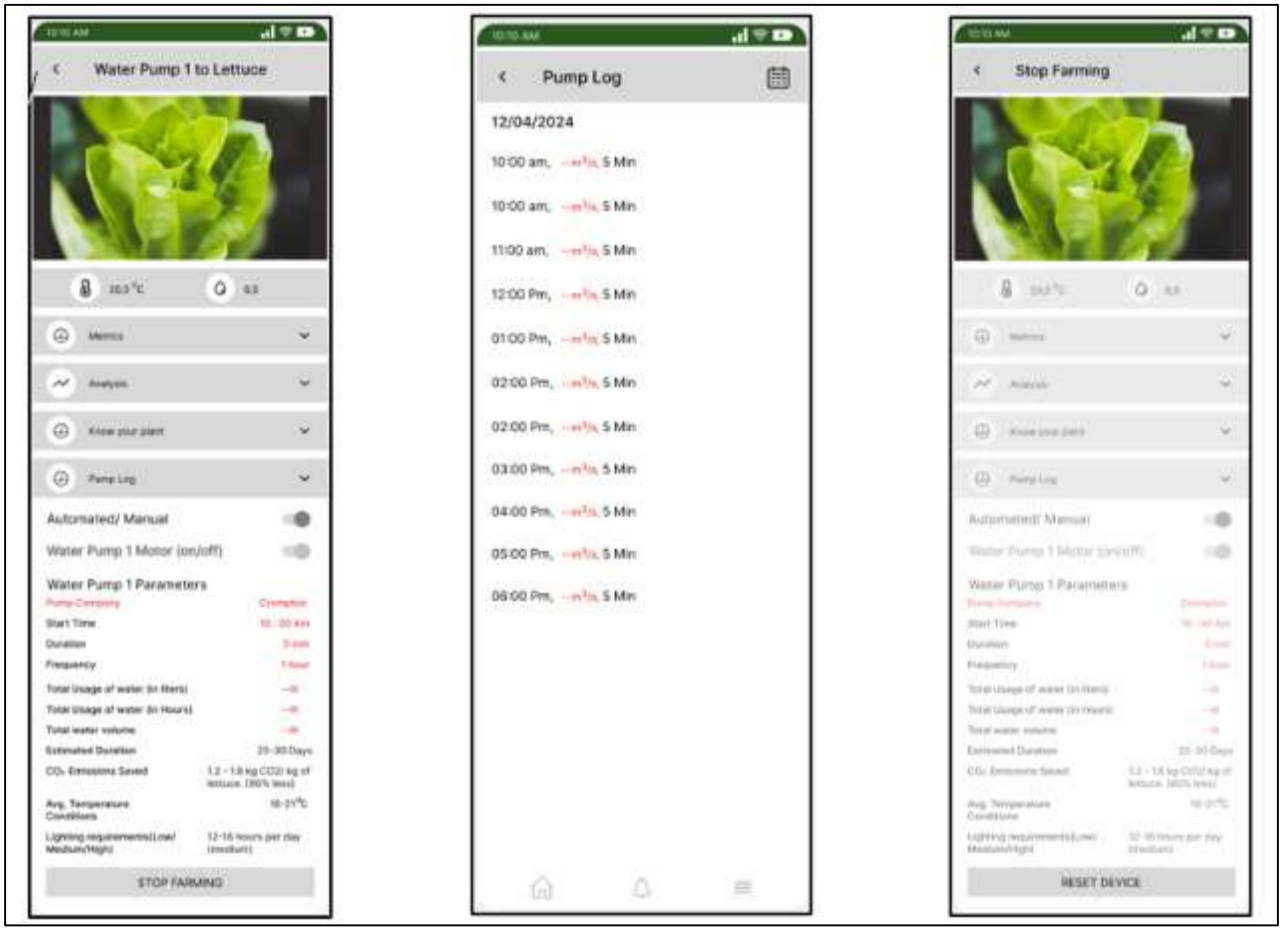

Figure 3 Real-time crop information provided to users

2.4. App Flow

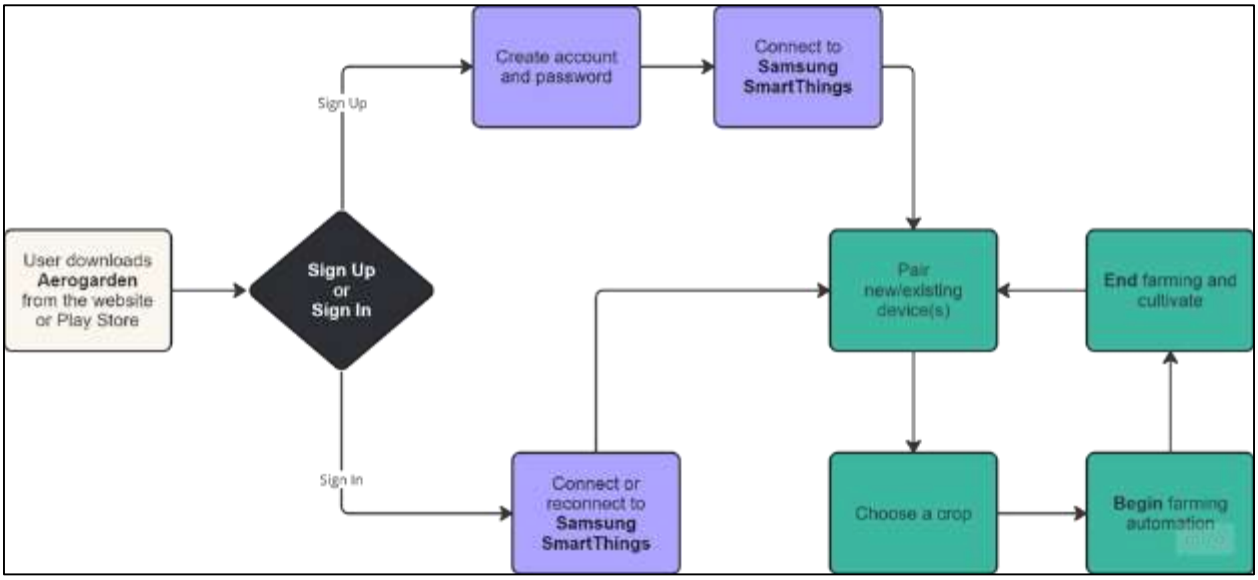

Figure 4 App Flow Representation

3. Results and Discussion

3.1. Data collection and analysis

Survey Conducted to Show Global Awareness: Prior to the creation and execution of the application, a survey was conducted to confirm and support the hypothesis. A sample size of 125 participants was taken at random from ages 15 and above from both genders. The end goal was to prove that the results align well with the hypothesis. Each question had the role of targeting a specific aspect of the hypothesis, ensuring all viewpoints and arguments are covered and corroborated.

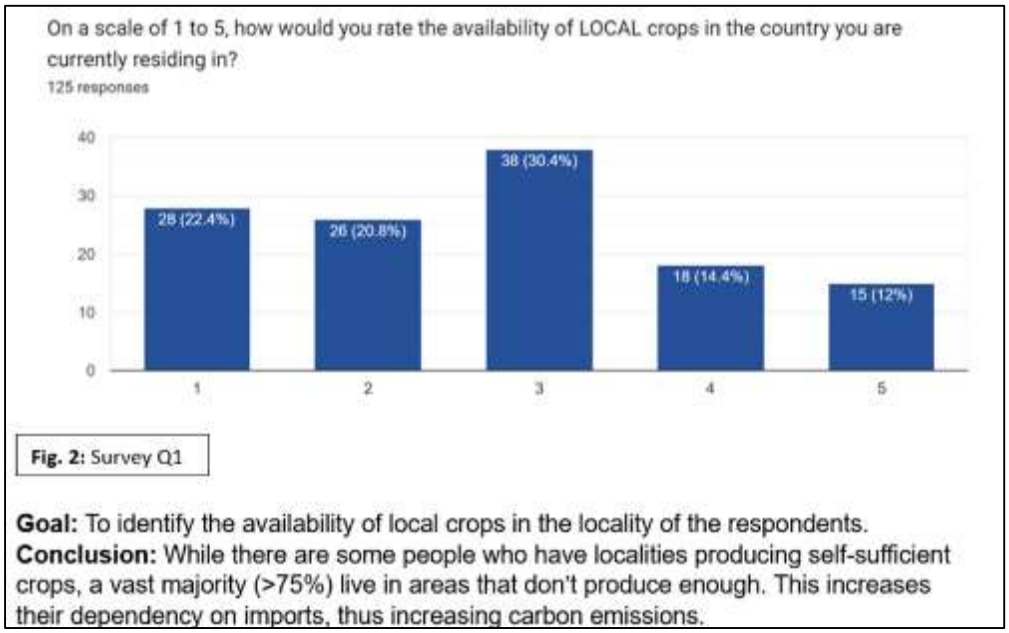

Figure 5 Survey Q1

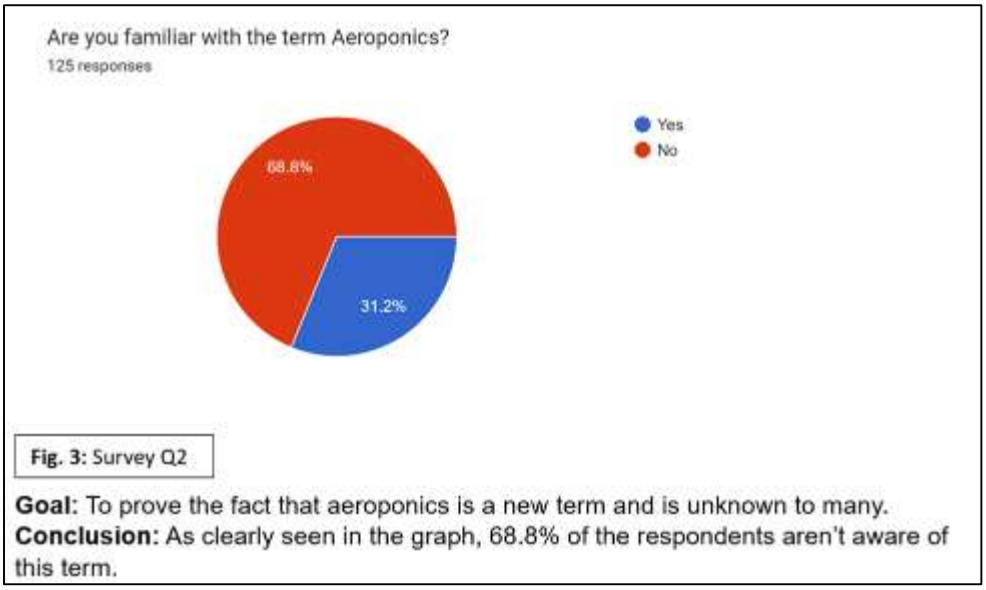

Fig. 3: Survey Q2

Goal: To prove the fact that aeroponics is a new term and is unknown to many.
Conclusion: As clearly seen in the graph, 68.8% of the respondents aren't aware of this term.

Figure 6 Survey Q2

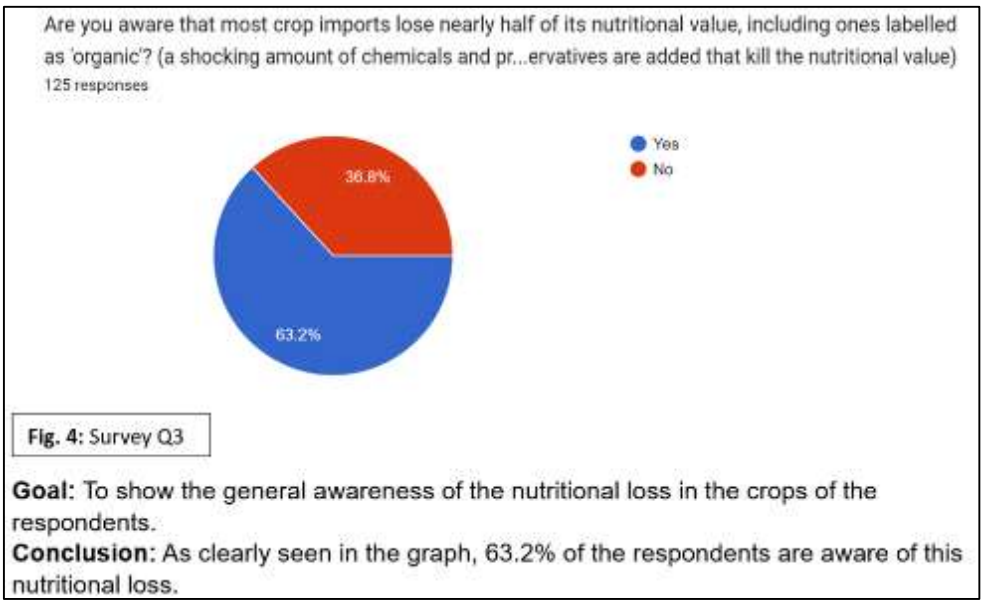

Fig. 4: Survey Q3

Goal: To show the general awareness of the nutritional loss in the crops of the respondents.
Conclusion: As clearly seen in the graph, 63.2% of the respondents are aware of this nutritional loss.

Figure 7 Survey Q3

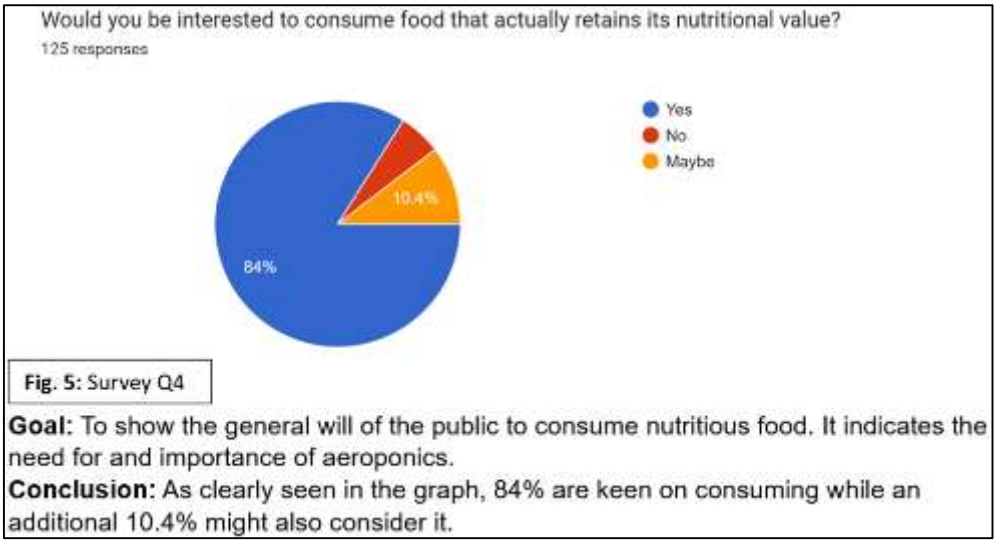

Figure 8 Survey Q4

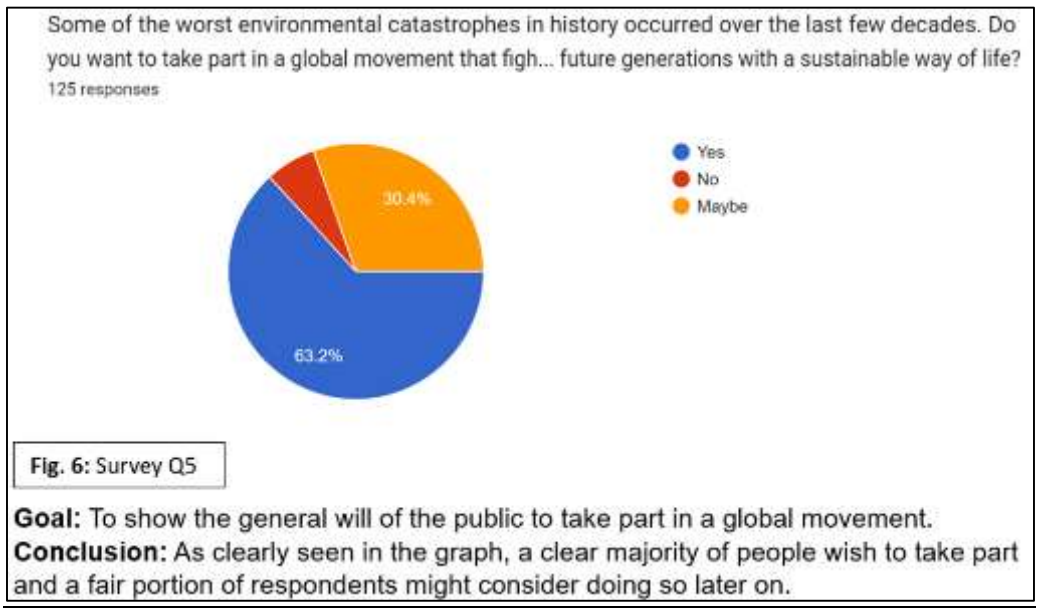

Figure 9 Survey Q5

4. Remarks

4.1. A Real Farmer's Experience

"Every minute, a farmer quits his job"

On 10th April 2024, I visited a local farm at a village named Loha Basa. I met a retired farmer and asked him about his experiences and struggles as a farmer in Jharkhand, India. He mentioned multiple constraints as a small-scale farmer and wishes to see changes in the future. Once I presented my idea about Project Aerogarden, he was ecstatic and appreciative. Farming is more than just hard labour; it's a culture that has been passed down through the years and is becoming less valuable due to financial constraints, geographical restrictions, social conflicts, and inequity. I've learnt valuable lessons from him. This experience gives more meaning to the aim of my project. It's time to put it into practice for a worthy cause.

Figure 10 A local farm in Loha Basa

4.2. Linking AI and Sustainability

While Aerogarden's identity revolves around modern technology, sustainability is also one of its core values. Aerogarden embraces sustainable innovation by providing means of green cultivation and minimal waste management, aligning with UN SDGs like SDG 2, Zero Hunger, (UN, 2012)[6] and SDG 12, Responsible Consumption and Production, (UN, 2012)[7]. It eliminates transportation waste and spoilage that occurs during long-distance travel by growing food directly in homes. Additionally, the precise delivery of nutrients through aeroponics reduces fertilizer runoff, which is a major contributor to water pollution. Furthermore, the modular design of Aerogarden encourages users to grow only what they need. This helps in minimizing food waste at the consumption stage. This hyper-local approach promotes a more sustainable food system, reducing environmental impact and empowering individuals to contribute directly to achieving the UN's broader sustainability goals.

One aspect currently under development for Aerogarden systems is the optimization of residual plant material. While the core focus is on edible portions, the stems, roots, and coconut husks (if used as a growth medium) present an opportunity for resourceful utilization. Research suggests potential avenues for this residual biomass. Stems with significant cellulose content could be composted or processed into biofuels. Roots, depending on the plant species, might hold value as natural dyes or hold promise in novel bioremediation techniques. Coconut husk, a popular aeroponic medium due to its high water retention, can be reused after sterilization or potentially composted at the end of its lifecycle.

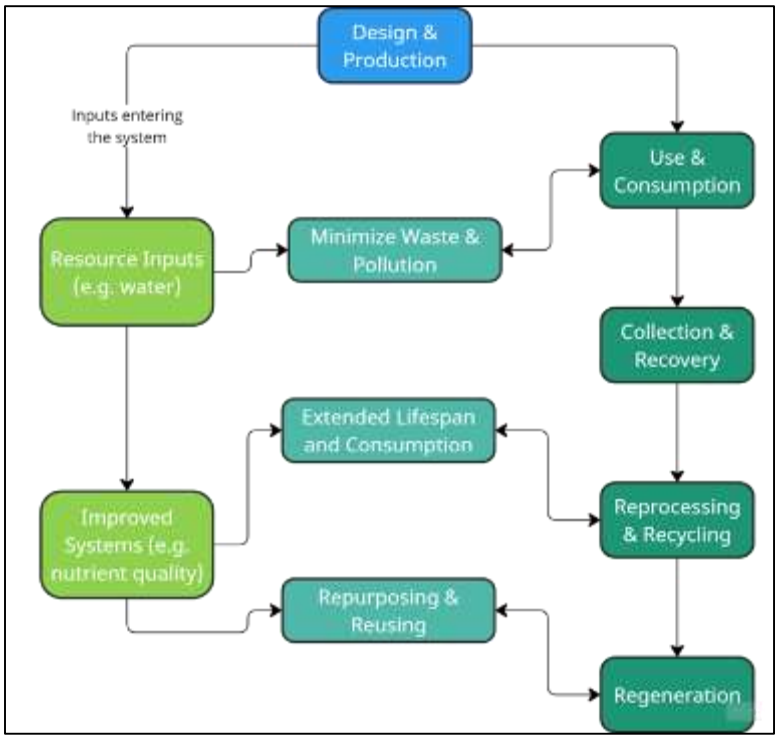

Figure 11 Circular Economy

4.3. Impact on the Circular Economy

The circular economy prioritizes eliminating waste and pollution at the design stage, then keeping products and materials in use for extended lifespans, ultimately aiming to regenerate natural systems. Firstly, the aeroponic system itself minimizes resource use, requiring less water and fertilizer compared to traditional agriculture. Secondly, the modular design encourages users to grow only what they need which helps in reducing food waste. Thirdly, the Aerogarden system itself can be designed with recycled materials or with a focus on disassembly and remanufacturing at the end of its lifecycle. Furthermore, research into upcycling residual plant material (such as composting stems, reassigning by-products generated as cattle feed, and reusing coconut husk) presents exciting possibilities for closing the loop within the Aerogarden system. By minimizing waste generation and maximizing resource utilization, Aerogarden promotes a more sustainable food production model that aligns with the circular economy's core principles.

5. Conclusion

The research paper's heavy emphasis on aeroponics and artificial intelligence makes it abundantly clear that these two topics have enormous potential for the future. The survey conducted has shown how most people live in areas that aren't self-sufficient in terms of crop production. Additionally, they lack awareness of new terms and concepts like aeroponics. However, they are aware of their food quality and a staggering number of these respondents wish to consume healthier food. Another point to note is that the majority of the respondents are interested in creating a global impact, directly or indirectly, for they care deeply for the planet and wish to make it sustainable for the future. Integrating modern technologies to address modern problems using solutions like Aerogarden should be an initiative that upcoming projects must have. The project's global impact will be groundbreaking if it succeeds in achieving its objectives

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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