



# Design and Development of a AEROGROW: Aeroponics farming system for Urban Areas

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## ABSTRACT

This project focuses on the design and development of a compact, low-cost aeroponic farming system aimed at promoting sustainable agriculture and efficient resource utilization. The study began with an in-depth literature review of existing aeroponic technologies, farming techniques, and their limitations. A functional system was conceptualized using 3D modeling tools, incorporating easily available materials such as PVC pipes, mist nozzles, and automatic timers. Components including a water pump, nutrient tank, and support frame were selected based on cost-efficiency and functionality. A balanced nutrient solution was formulated to maintain optimal pH and EC levels for plant growth. Fast-growing leafy crops such as lettuce and spinach were chosen and placed in net pots with roots suspended in a mist chamber. The system was operated using timed misting cycles and monitored for environmental parameters and plant development. Performance analysis compared the aeroponic system with traditional soil-based methods, evaluating water, nutrient, and electricity consumption as well as crop yield. The results indicated that the aeroponic setup offers significant advantages in terms of water efficiency, growth rate, and space utilization, making it a viable alternative for urban and resource-limited agriculture.

## KEYWORDS

Aeroponics, sustainable agriculture, hydroponic systems, nutrient solution, vertical farming, smart farming, root misting, precision agriculture, resource efficiency, soil-less cultivation.

## I. INTRODUCTION

With the rapid growth of the global population and the increasing demand for food, traditional agriculture is under immense pressure to produce more using limited land and water resources. Soil degradation, water scarcity, and the overuse of chemical fertilizers have further emphasized the need for innovative, sustainable farming techniques. Among these, **aeroponics**—a method of growing plants without soil by suspending roots in air and nourishing them with nutrient-rich mist—has emerged as a highly efficient alternative.

Aeroponic systems offer numerous advantages over conventional farming, including reduced water usage, faster plant growth, and minimal space requirements. These benefits make aeroponics particularly suitable for urban environments, vertical farming, and resource-constrained regions. Despite its potential, the widespread adoption of aeroponics is often hindered by the high cost and technical complexity of commercial systems.

This project aims to design and develop a low-cost, compact aeroponic system using readily available materials and simple automation techniques. The goal is to create a functional prototype that can support healthy plant growth while being affordable and easy to maintain. The system includes essential components such as a water pump, misting nozzles, a nutrient delivery

mechanism, and environmental monitoring tools. Leafy greens like lettuce and spinach are chosen for cultivation due to their rapid growth and suitability for aeroponic environments.

Through this project, the feasibility, efficiency, and performance of the designed system will be analyzed and compared with traditional soil-based cultivation methods. The research ultimately contributes toward promoting sustainable agriculture and increasing food production in a technologically efficient and environmentally responsible manner.



Figure 1: Theme Board and Mood board

## II. LITERATURE REVIEW

The growing interest in sustainable agriculture has brought aeroponics to the forefront, as documented in a wide array of literature ranging from academic journals to applied research and systematic reviews. In *"Aeroponics: An Emerging Food Growing System"* (Elsevier), the TAISA model and AI integration are highlighted as essential for adoption and automation, offering precision control and faster plant growth; however, the system remains highly dependent on power and sensitive sensors. Katrahalli Sharat's *Seminar Report on Aeroponic Farming Technology* emphasizes 98% water savings and 60% less fertilizer usage, ideal for space-limited urban areas, though it suffers from high initial costs and frequent mist nozzle clogging. Kumari and Kumar's scientific review builds on NASA's work, reporting 80% higher dry biomass production, disease-free environments, and micro-climate management, but notes the requirement of technical expertise and expensive setups. Similarly, *Aeroponics in Vegetable Crops* shows the ability to produce up to 100 minitubers per plant while saving 90–95% water, yet faces risks of system failure and high energy consumption. In the context of urban sustainability, *Vertical Farming – Smart Urban Agriculture* outlines 100x crop yield potential with 70–90% water savings, enabled by IoT and AI, though it is energy-intensive and limited in crop diversity.

Further refinement is seen in the *Aeroponics Soilless Cultivation System for Vegetable Crops*, where systems show 99% water conservation and up to 75% higher yield, with easy monitoring and a vertical format; still, cost and clogging remain concerns. A more portable solution is proposed in the *Sustainable Inflatable Aeroponics Smart Farm*, which can grow 250 plants using just 40L of water in three weeks, offering high efficiency and mobility, but it demands technical skill and upfront investment. An environmental angle is added by the *Aeroponic Container Farms in Sustainable Food Systems* (LCA study), showing a carbon footprint of 1.52 kg CO<sub>2</sub>eq/kg (UK Grid), with an 80% reduction when powered by renewables, yet remains fossil fuel dependent in most current setups. In a methodological contribution, the *Modified Aeroponic System for Small-Seeded Legumes* introduces an affordable root observation setup, which is reusable and cost-effective for research, though root behavior may differ from soil-based systems. A general review paper consolidates findings, emphasizing 95% water savings and rapid crop turnover, supporting year-round farming, but again points out the need for stable power and significant investment. The *Systematic Review of Technology in Aeroponics* analyzes 47 studies and affirms the efficiency and sustainability of such systems using the TAISA model, though warns of complex installation and power-related vulnerabilities. Finally, *Getting to the Roots of Aeroponic Indoor Farming* documents 65% higher yields in crops like red kale, attributing it to improved oxygen and nutrient absorption, but also flags issues like infrastructure needs and energy dependency.

Collectively, these studies showcase the immense potential of aeroponics in addressing urban food challenges through high resource efficiency, space optimization, and smart integration of technology, while also underlining recurring challenges such as high costs, technical complexity, and reliance on stable power sources. These insights help shape future directions for making aeroponics more accessible, resilient, and scalable for diverse urban contexts.

This section explores the foundational concepts behind aeroponics and its role in urban agriculture. Aeroponics is defined as a soil-less method of growing plants where roots are suspended in air and misted with nutrient-rich solutions, leading to enhanced oxygenation and nutrient uptake. Compared to traditional farming, aeroponics is far more efficient—using up to 95% less water, eliminating soil-borne diseases, and supporting faster, higher-yielding plant growth in compact spaces.

The section also traces the evolution of urban agriculture, from basic rooftop gardens to sophisticated systems like vertical farming and Controlled Environment Agriculture (CEA). Aeroponics stands out as an ideal innovation in this context, offering scalability, efficiency, and sustainability.

Further, the integration of sensors and automation is discussed in detail. Devices such as pH sensors, TDS sensors, and water level indicators provide real-time monitoring of essential parameters. Automation via timers and microcontrollers ensures consistency and reduces manual intervention. These technologies enable smart farming by improving efficiency, minimizing labor, and supporting data-driven crop management in urban aeroponic systems.

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### 2.1 Market Trends and Industrial Relevance

As of 2023, the global aeroponics market is valued at USD 1.5 billion, expected to exceed USD 3.5 billion by 2030 with a CAGR of 12–15%. Key players include:

- AeroFarms, Tower Garden, LettUs Grow, and Ponics Technologies (India). These companies offer modular, app-integrated, and educational systems for both urban and commercial applications.

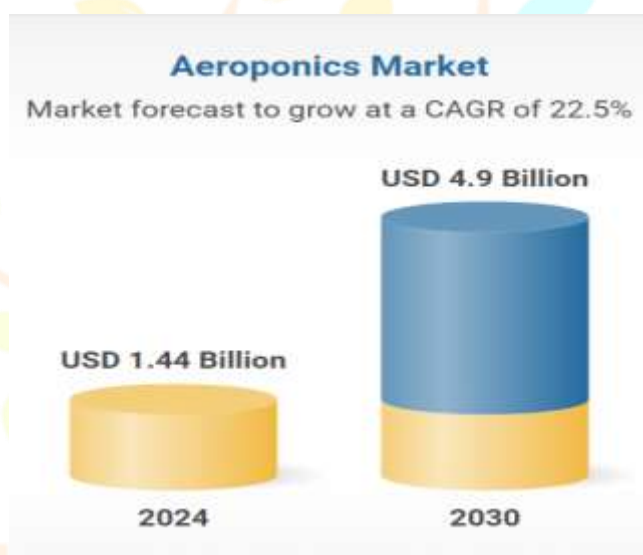


Figure 2: Graph

### 2.2 Key Takeaways and Research Gaps

The literature reviewed on aeroponic farming technologies consistently highlights several significant benefits, making it a promising solution for urban agriculture. Among the most frequently cited advantages are up to 99% water savings, yield improvements ranging from 45–75%, and the efficient use of vertical and modular designs that optimize limited urban space. Aeroponics also enables year-round cultivation of pesticide-free crops, contributing to improved food security and local food production. Moreover, the integration of smart technologies like AI, IoT, and sensor-based systems facilitates real-time monitoring and automation, reducing the need for manual labor and increasing precision in nutrient delivery. However, these benefits are counterbalanced by several challenges. Most systems suffer from high initial setup costs, technical complexity, and dependency on consistent power supply. Additional issues such as nozzle clogging, sensor malfunction, and system failure risks are prevalent, particularly in energy-intensive vertical farms. Furthermore, the affordability and scalability of aeroponics remain limited, especially for adoption in low-income or rural contexts. A significant research gap lies in the lack of compact, cost-effective designs that are suited for small-scale urban households, such as those in apartments or limited rooftop areas. While current systems demonstrate technical efficiency, very few incorporate user-friendly features or consider the needs of urban dwellers with limited space and resources. This thesis addresses that critical gap by proposing a smart, hybrid aeroponics-hydroponics system that is compact, automated, and affordable, specifically designed for balconies and rooftops in urban environments, thereby promoting inclusive access to sustainable food production.



Figure 3: Overview of Aeroponic farming

### III. METHODOLOGY

A structured methodology was followed to design and develop a compact aeroponic system. The project began with a thorough literature review to understand existing aeroponic systems, sustainable farming methods, and limitations in current commercial setups. This review laid the foundation for identifying key gaps in affordability, accessibility, and system efficiency. The conceptual design phase involved sketching and modeling the proposed system using basic CAD tools. Emphasis was placed on creating a compact, modular structure using cost-effective and easily available components such as PVC pipes, mist nozzles, a timer, and a water pump.

The selection of components was driven by functionality, availability, and cost-efficiency. A prototype was built using a grow chamber, net pots, foam collars, and a misting system supported by an automatic timer to deliver nutrient mist at regular intervals. A balanced nutrient solution was prepared based on hydroponic standards, and pH and EC values were maintained within the optimal range (5.5–6.5 for pH). Fast-growing leafy greens like lettuce and spinach were selected for cultivation due to their short growth cycle and adaptability to aeroponic conditions.

The system was continuously monitored for environmental parameters such as humidity, temperature, and water levels, as well as plant health indicators including root development, stem height, and leaf size. Observational data were logged regularly to track growth progress and system performance. To evaluate the efficiency of the designed setup, resource consumption (water, electricity, nutrients) was measured and compared to conventional soil-based cultivation.

Throughout the process, iterative refinements were made based on functional testing, nutrient flow behavior, and root exposure. The final analysis focused on performance metrics such as crop yield, resource efficiency, and cost-effectiveness. This methodical approach ensured that the developed aeroponic system is not only functionally robust but also scalable and practical for urban farming and resource-constrained environments.

### Product development stages from initial idea to final product.

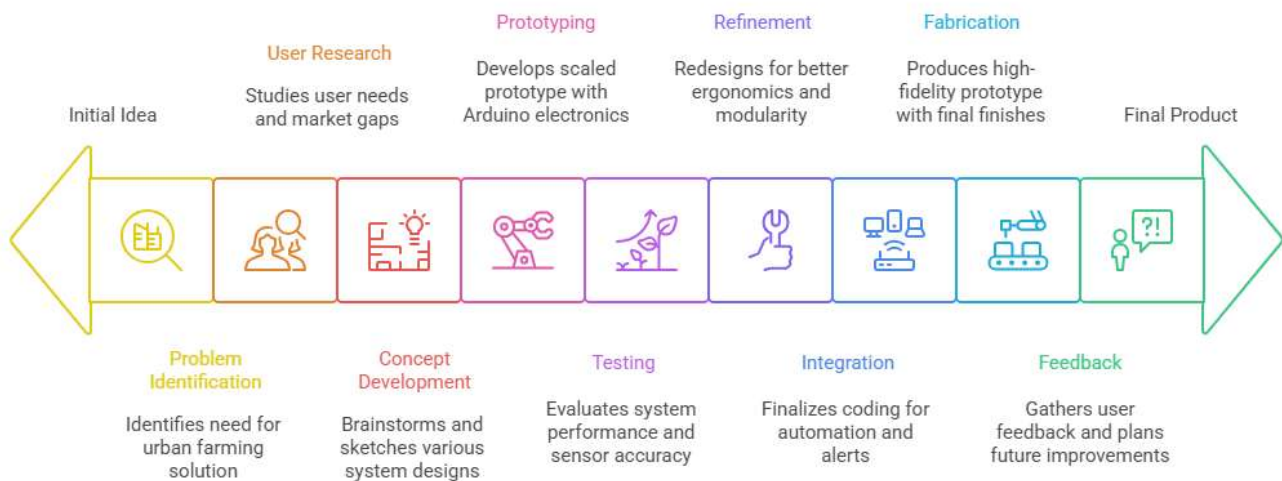


Figure 4 : Developing an aeroponic system

#### IV. PRODUCT DESIGN AND DEVELOPMENT

##### 4.1 Concept Finalization

Concept 5 was selected aeroponic system concept was finalized based on its compact layout, cost-effectiveness, and ease of assembly using readily available materials. The design integrated insights from the literature review and practical constraints of urban farming. Emphasis was placed on minimal spatial footprint, modular construction, and optimal nutrient delivery. The system layout included vertically arranged net pots, a sealed misting chamber, and an automated nutrient mist delivery mechanism. CAD tools like Fusion 360 were used for component layout and visualization. The design allows for easy scalability, repair, and cleaning. User accessibility and simplicity in operation were prioritized to cater to students, urban gardeners, and small-scale growers.

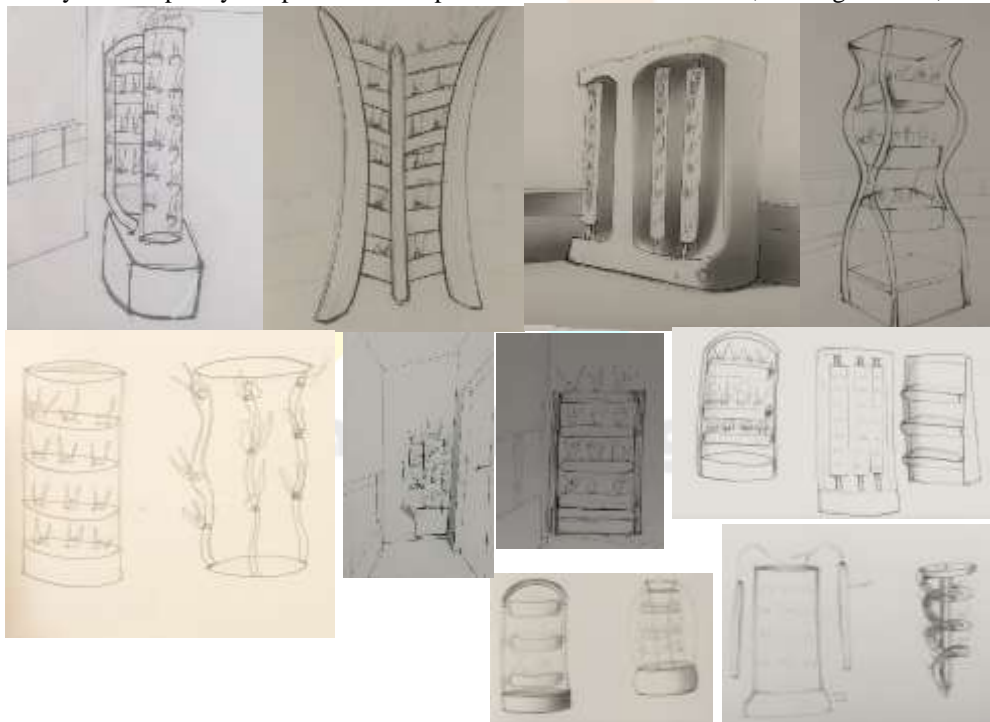


Figure 4 concept sketch



Figure 6 (a) fusion 360 model, (b) rendered model, (c) Environmental rendering

#### 4.2 Technical Features

The final system features a misting chamber with root suspension capability, a nutrient reservoir, and an automatic timer that regulates misting cycles (e.g., 5 seconds every 2–3 minutes). A submersible water pump delivers the nutrient solution to mist nozzles arranged uniformly to ensure even root coverage. The nutrient solution is monitored using pH and EC meters, maintaining optimal values (pH 5.5–6.5, EC 1.0–2.5 mS/cm). The system supports up to 6–12 plant holders arranged vertically or horizontally based on space. The root chamber is light-proof and air-tight to prevent microbial growth and promote healthy root development. Environmental parameters (humidity, temperature) are tracked manually or via low-cost sensors for data-driven analysis..

#### 4.3 Materials and Mechanism

Materials were selected based on cost, availability, and durability. PVC pipes and fittings were used for the frame and nutrient delivery lines due to their low cost and corrosion resistance. The misting nozzles were standard hydroponic-grade atomizers connected via flexible tubing. A plastic storage container was repurposed as a sealed root chamber to maintain high humidity and darkness. Foam collars and net pots were used to suspend seedlings. An electronic timer was employed to automate misting intervals, reducing manual intervention. The system is modular and lightweight, allowing easy relocation and expansion. Key mechanisms such as mist dispersion and root suspension were tested iteratively to ensure optimal functionality.

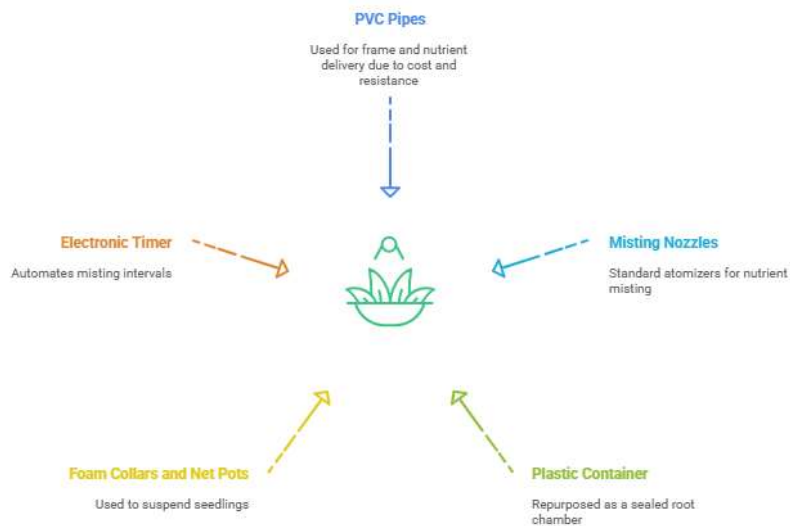


Figure 7 Components of Aeroponics system

## V. VALIDATION AND TESTING

The prototype was tested over a growth cycle using fast-growing crops like lettuce and spinach. Regular observations were recorded for root development, stem growth, and leaf size. The misting system performed consistently, and nutrient absorption was found to be uniform across all plants. Water and nutrient usage were tracked and showed significantly lower consumption compared to soil-based cultivation. Minor adjustments were made to misting duration and nozzle angles for better coverage. pH and tds values were maintained using manual calibration. The system demonstrated good structural stability and was easy to maintain. Users (students and gardening hobbyists) provided feedback highlighting ease of use, cleanliness, and fast plant growth. These insights confirmed the design's effectiveness and suitability for urban or small-scale farming environments. Final analysis showed that the aeroponic system met its design goals of efficiency, sustainability, and accessibility.

## VI. CONCLUSION AND FUTURE WORK

The project successfully delivers a compact and cost-effective aeroponic system designed to support sustainable agriculture and efficient crop production, especially in urban and space-constrained environments. The final prototype integrates user-centered design, modular assembly, and optimized nutrient delivery, ensuring healthy plant growth with minimal resource consumption. By utilizing easily available materials such as PVC pipes, misting nozzles, and automated timers, the system offers an accessible solution for both educational and small-scale agricultural applications.

This study emphasizes the importance of incorporating iterative testing, environmental monitoring, and real-world feedback in refining system performance. The results highlight the aeroponic system's superiority in water and nutrient efficiency when compared to traditional soil-based methods. Future enhancements may include sensor-based automation, remote monitoring via IoT integration, and scalability for larger vertical farming applications.

The successful implementation of this prototype demonstrates the potential of affordable, locally built aeroponic systems to transform urban farming practices. It supports national goals for sustainable development, water conservation, and food security. The approach and methodology used in this project serve as a foundation for future innovations in precision agriculture, enabling more inclusive and environmentally responsible farming solutions.

While the current prototype validates the core design and user requirements, several opportunities for enhancement remain:

- **IoT Integration:** Future versions will include real-time app connectivity, enabling users to receive alerts for pH, TDS, misting cycles, and water levels via smartphone.
- **AI-Based Recommendations:** Integration of machine learning algorithms to recommend nutrient levels, crop schedules, and environmental settings.
- **Scalability:** Expanding the system into multi-tier stackable units for community gardens, schools, or semi-commercial urban farming.
- **User Education:** Developing interactive onboarding tutorials and a community platform to share growing tips and system usage.
- **Material Optimization:** Exploring biodegradable and recycled materials to enhance environmental sustainability further.

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