SMART AQUASYNC: AN IOT-INTEGRATED SYSTEM FORSUSTAINABLE AQUACULTURE AND HYDROPONIC CULTIVATION, ENHANCING EFFICIENCY IN AQUAPONICSAND AGROTECH MANAGEMENT

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Abstract— The IoT-based Aquaponics Monitoring System is an innovative and sustainable farming solution that combines aquaculture and hydroponics. It utilizes a network of sensors and collectors to collect real-time data on crucial environmental parameters such as water quality, nutrient levels, and fish behavior. These sensors are connected through control and wireless communication via a centralized mobile application platform accessible on smartphones. Utilizes a Arduino UNO, a PH sensor, an ultrasonic sensor, a DHT11 sensor, and a servo motor for controlling and monitoring purposes. Further, PH sensor, DHT11 sensor, and ultrasonic sensor are also connected to Arduino UNO to monitor PH levels, humidity, temperature, and water level. Key features include data analytics, automatic alerts for out-of-range parameters. The system allows for historical analysis and decision-making, empowering aquaponic farmers to enhance efficiency and sustainability. Overall, it offers increased productivity, reduced resource consumption, and minimized environmental impact, contributing to the advancement of sustainable agriculture.

Keywords— Arduino UNO, Automatic Sensor, DHT11 Sensor, Historical data analysis, Hydroponic cultivation, Nutrient levels, pH sensor, Ultrasonic sensor.

I. INTRODUCTION

Aquaponics is an innovative farming method that synergizes aquaculture and hydroponics, using fish waste to nourish plants in a closed-loop system. This approach excels in efficiency, and usage of less water to give more yielding than traditional farming.

The Internet of Things is instrumental in reshaping daily life by ensuring swift data exchange and minimal communication errors. In aquaponics, IoT automation preserves a healthy ecosystem, providing stakeholders with real-time data, notifications, and insights. This transformative innovation has the potential to revolutionize sustainable food production.

The incorporation of technology into traditional farming practices has given rise to inventive solutions for sustainable agriculture. Aquaponics, the fusion of aquaculture and hydroponics, maximizes resource utilization and minimizes environmental impact. This article explores the transformative potential of an IoT-Integrated Aquaponics monitoring and mobile application in enhancing the efficiency, sustainability, and management of aquaponic ecosystems.

Aquaponics creates a symbiotic relationship between aquatic life and plant cultivation in a closed-loop system. Fish waste fertilizes plants, purifying water for the fish. Addressing food security and environmental sustainability challenges, aquaponics reduces water consumption, boosts productivity, and minimizes the ecological footprint of traditional farming.

Integrating the Internet of Things into aquaponics transforms the control of crucial parameters. Sensors collect real-time data on pH, temperature, dissolved oxygen(O2), and nutrient concentrations, enabling automated adjustments through a central control unit. A user-friendly mobile application empowers farmers with real-time insights, alerts, and remote management capabilities.

Aquaponics excels in sustainability, notably reducing water usage compared to traditional farming. The closed-loop system continuously recycles water, mitigating the need for additional irrigation. This water-saving feature is especially vital in regions facing water scarcity, positioning aquaponics as a sustainable solution to agricultural challenges.

A cutting-edge initiative in the realm of sustainable agriculture, specifically targeting aquaculture and hydroponic cultivation. This innovative model is designed to harness the power of the IoT, integrating advanced technologies to revolutionize the efficiency and management of both aquaponics and agro-tech practices. With a commitment to resource conservation, the smart aquasync system aims to redefine conventional approaches by seamlessly merging aquaculture and hydroponics, thereby fostering a holistic and sustainable farming solution. This introduction sets the stage for a comprehensive exploration of the system's capabilities in optimizing agricultural processes, while prioritizing environmental sustainability and technological integration.

II. LITERATURE SURVEY

The study's literature review is condensed into a table, offering a thorough summary of pertinent research endeavors. The table includes essential information such as the study's title, author(s), year of publication, research goals, and noteworthy strengths and weaknesses identified in each investigation.

Year	Title	Authors	Objectives	Advantages	Disadvantages
2017	Design of aquaponics water monitoring system using Arduino microcontroller. [1]	S. A. Z. Murad, A. Harun, S. N. Mohyar, R. Sapawi, S. Y. Ten	1.The system focuses on preserving and overseeing water resources, minimizing agricultural water consumption, and Combining aquaculture With hydroponics environments. 2. It is equipped to send mobile notifications via GSM when water parameters deviate from acceptable ranges, and it relies on solar energy for its power source.	1. The aquaponics system with Arduino ensures optimal water conditions through real-time monitoring, automated pH control, and remote notifications. 2. Its sustainable features, simplified programming with Arduino IDE, and solar-powered operation make it efficient.	1. Challenges include reliance on GSM in areas with limited network coverage, system Complexity requiring Regular maintenance, initial setup costs, and the need for ongoing water testing. 2. Despite these, the system offers an effective and sustainable solution for aquaponics.
2018	Smart Aquaponics System: Design and Implementation using Arduino Microcontroller. [2]	C.K.Cheong, A.M.K.Iskandar,A.S.Azhar, W.A.F.W. Othman	1. The system aims to minimize water usage, eradicate reliance on chemical pesticides , and offer a sustainable farming solution Through mechatronics technology. 2. The prototype incorporates recycled materials, validates the functionality of the aquaponics system, and tackles challenges like component interference And microcontroller compatibility.	1. The aquaponics system promotes environmental sustainability, reduces Water consumption, and eliminates the use Of chemical fertilizers. 2. Its low-cost design Enhances accessibility For small-scale farmers.	1. Technical complexity: The system faces challenges related to its intricate technical design. 2. Regular maintenance requirements: Ongoing upkeep demands may pose a hurdle for users.

2018	IoT based Aquaponics Monitoring System. [3]	Abhay Dutta, Prayukti Dahal, Rabina Prajapati, Pawan Tamang, Er. Saban Kumar K.C	1. Enhance communication using Raspberry Pi and Relay module 2. Utilizes a 16x2 Liquid Crystal Display for on-site data presentation and incorporates IoT for remote access. .	1. Real-time monitoring enhances plant and fish health in the IoT Aquaponics System. 2. The system promotes sustainability with a focus on dual income streams.	1. High costs pose financial challenges in agriculture. 2. Overreliance on technology creates vulnerabilities.
2019	Implementation of Aquaponics With in IoT Framework. [4]	Muhammad Fasih Uddin Butt, Raziq Yaqub, Maryam Hammad, Moaz Ahsen, Muneeb Ansir, Nida Zamir	1..continuous monitoring facilitated by embedded sensors, the research seeks to create a smart aquaponic system that can be remotely controlled and analyzed in real-time. 2. Maximize agricultural yield, minimize human error, and enable proactive Measures for unforeseen challenges.	1. Aquaponics with IoT boosts yield, minimizes errors, and allows remote monitoring, fostering proactive issue detection. 2.Continuous monitoring provides valuable data for improvement.	1.Technical requirements: This system demands specific Technical prerequisites that may be challenging for some farmers. 2.Dependence on stable internet and power: Reliable internet and power access are crucial for the effective functioning of the IoT system, posing challenges in regions With unstable infrastructure.

Year	Title	Authors	Objectives	Advantages	Disadvantages
2019	Smart aquaponic system based Internet of Things (IoT). [5]	Haryanto, M Ulum, A F Ibadillah, R Alfita, K Aji, R Rizkyandi	1. Enhance the accuracy and reliability of sensors, testing Quality of Service parameters for effective data transmission, and providing real-time access to information through a mobile application and internet-based platform. 2. Monitor and analyze the cultivation of plants and fish within the system While contributing valuable insights to the field of aquaponics research.	1.The smart aquaponics System optimizes resource use through a Symbiotic relationship between aquaculture and hydroponics. 2.Real-time monitoring via sensors and mobile app ensures accurate data collection, contributing to system health. 3.The technology enables remote control and accessibility through IoT integration, making it a sustainable solution for agriculture.	1.Challenges include pH sensor inaccuracies, the impact of high temperatures on plant growth, and concerns regarding Quality of Service in the network infrastructure. 2.Addressing these areas is crucial for enhancing the system's overall effectiveness.
2020	Development and Evaluation of Environmental / Growth Observation Sensor Network System for Aquaponics. [6]	Yusuke Haruo, Hiroshi Yamamoto, Masao Arakawa, Itsuo Naka	1. Integrates a depth camera module to capture detailed plant shapes, utilizing both RGB and depth images to automatically quantify the growth condition of plants . 2. Analyze the correlation between growth conditions and Environmental information, utilizing Machine learning technologies such as regression analysis and Support Vector Machine (SVM).	1.Aquaponics system automation ensures a stable income for users. 2.Bacterial activity is optimized within the system. 3.Remote monitoring capability enhances overall system management.	1. Lack of direct control over bacterial activity poses a challenge. 2. Reliance on expert knowledge may be a limitation. 3. Bluetooth Low Energy communication issues can impact system connectivity.

2020	Aquaponics for Agriculture using IOT. [7]	Maryam Jawadwala, Yogesh Pingle	1. Emphasizing the significance of soilless farming for overcoming soil-related issues and ensuring natural growth of plants. 2. Collected data from the sensors can be monitored using the Blink application, providing real-time insights into the system's conditions.	1. Aquaponics combines aquaculture and hydroponics, offering space-efficient, water-saving, and sustainable agriculture. 2. It provides a continuous, eco-friendly nutrient source for fish and plants, enabling year-round crop production without relying on fertile soil.	1.Drawbacks include initial setup costs, technical expertise requirements, energy dependency, and the risk of system failures. 2. While efficient, aquaponics may have limitations for certain crops, and there could be a learning curve for operators.
2020	IoT based water quality monitoring system for aquaponics. [8]	Muhamad Farhan Mohd Pu'ad, Khairul Azami Sidek, Maizirwan Mel	1.Develop a system capable of providing real-time measurements and data analysis to optimize aquaponics conditions. 2. Create a web-based dashboard for user-friendly access to monitoring data, enhancing convenience and accessibility. 3. Ensure that the system operates stably and reliably, contributing to the sustainability and success of aquaponics practices.	1. Enables users to Monitor aquaponics systems from any location, promoting flexibility and convenience. 2. Contributes to Environmentally friendly agriculture by optimizing water quality and promoting efficient resource use. 3. Utilizes common low- cost electronics and open- sources oftware, potentially reducing implementation costs.	1. The system focuses primarily on pH levels, omitting monitoring of other water quality parameters. 2. Relies on stable internet connectivity for remote access, which may be a limitation in areas with poor connectivity. 3. Based on the choice of cloud services, additional costs for hosting and storage may be incurred.

Year	Title	Authors	Objectives	Advantages	Disadvantages
2020	Developmet of an Automated Aquaponics System with Hybrid Smart Switching Power Supply.[9]	Jerome Christian C. Egargue, Frederick A. Pacaigue, Raymund Glor F. Galicia, Engr. Glenn V. Magwili	1. The primary objective is to build an Automated Aquaponics System with a Hybrid Smart Switching Power Supply. 2. Smart switching power supply, comparing energy consumption with related research, determining dump energy, and evaluating fish and plant growth.	1. The Automated Aquaponics System provides sustainable urban agriculture, minimizing reliance onthe grid. 2. It efficiently utilizes resources and allows real- time monitoring ofsystem conditions.	1. System effectiveness may be influenced by weather conditions. 2. Sunlight availability impacts solar power generation and system performance.
2021	IoT-Based Smart Aquaponics System Using Arduino Uno.[10]	Mpho P. Ntulo , Pius. A Owolawi, Temitope Mapayi, VusiMalele, Gbolahan Aiyetoro, Joseph S. Ojo	1. Use of Arduino Uno asthe central microcontroller, interfaced with varioussensors and actuators 2. Water pumps are controlled based on sensor readings, and data is analyzed and presentedin real-time.	1. Aquaponics optimizes water usage forsustainable cultivation. 2. Yields organic producethrough environmentally friendly practices. 3. Year-round operation is facilitated by the integration of IoT monitoring.	1. Technical expertise is required for system implementation and management. 2. Energy consumption is a consideration in systemoperation. 3. Managing fish health poses a challenge.
2022	An Smart Aquaponic System Using IoT.[11]	Shaiz Akhtar Mohammad , Daggumalli Sai NikhilaCho w dary, Dr. R. Jebakumar	1. Develop a system that fosters sustainable practices by creating a symbiotic relationship between fish and plants, utilizing fish waste as nutrients for plant growth, and reciprocally purifying water for fish. 2. Resource Efficiency: Reduce the reliance on pesticides and water by up to 90%, contributing to resource conservation and minimizing the environmental impact Associated with conventional farming.	1. Aquaponics utilizes fish waste as nutrients forplants, and plants act as biofilters, cleaning the water for fish, creating asymbiotic relationship. 2. With a decrease in theusage of pesticides and water, aquaponics contributes to environmental conservation.	1. Maintenance: Regularmaintenance is required to ensure the proper functioning of electronic components and prevent system failures. 2. Energy Consumption: Continuous operation of IoT devices may lead to increased energyconsumption.

2022	Smart Plant Monitoring System Using Aquaponics Production Technologic alwith Arduino Developmet Environment (IDE) and SMS Alert: APrototype. [12]	Zahari Abu Bakar, Muhammad Zairil Muhammad Nor, Kamaru Adzha Kadiran, Mohamad Farid Misnan, Maisarah Noorezam	1. Present the mobile dashboard displaying real-time data from the sensors and the notification system, which alerts the user to any abnormal conditions of aquaponics system. 2. Provide a visual representation of the flowchart illustrating the working of the Smart Plant Monitoring System.	1. The Smart Plant Monitoring System integrates aquaponics and IoT, offering sustainable agriculture. 2. It enhances resource efficiency, provides real- time monitoring, and automates processes, reducing risks and improving yields. 3. The system's wirelessremote monitoring adds flexibility for farmers, contributing to economic growth.	1. Challenges include initial implementation costs, technical expertise requirements, and potential accessibility issues for small-scale farmers. 2. Dependence on technology introduces risks like technical failures and disruptions. 3.Environmental concerns related to e-waste and scalability uncertainties are also notable.

Year	Title	Authors	Objectives	Advantages	Disadvantages
2022	Development of IoT Based Aquaponic Monitoring System for Agriculture Application. [13]	Muhammad Al Baihaqi MatRani, Izanoordina Ahmad	1. Aquaponic System Development: The primary objective is to develop an aquaponic monitoring system using IoT (Internet of Things)technology. 2. IoT Parameters Monitoring: Implementing sensors to monitor key parameters in the aquaponic system, such as level of water, temperature, pH, and soilmoisture.	1. Chemical-Free Agriculture: Aquaponicseliminates the need for pesticides, herbicides, and fertilizers, providing a 100% chemical-free foodproduction system. 2. Resource Efficiency: The system utilizes fish waste as a natural fertilizer, creating a closed-loop system that maximizes resourceefficiency.	1. Limited Coverage: The WiFi range may limit the coverage area of the monitoring system, posing a challenge in larger agriculturalsettings. 2. WiFi Stability Issues: Instabilities in WiFi connections can lead to faults in data transmission, affecting the reliability of thesystem.
2023	Iot based aquaponics monitoring System. [14]	Manjula H J,andhini K R, Dr.Rashmi SBhaskar, Namratha S	1. The system stores data in a cloud-based server, enabling historical tracking and analysis of water quality parameters. This can help identify patterns and trends overtime. 2. The inclusion of a GSMmodule enables thesystem to send alertmessages to operators incase of deviations fromthe defined water quality ranges. This timely notification ensures prompt actions can be taken to rectify any issues.	1. The aquaponics monitoring system excels in real-time tracking, automation, and IoTaccessibility. 2. Cost-effective with Arduino, it offers data storage for historicalanalysis.	1. Challenges include dependence on technology, demanding technical expertise, an initial setup cost barrier, and potential oversight of critical aquaponics factors. 2. Environmental oncerns stem from electronic components and potential e-waste.
2023	Automated Aquaponics Farming usingInternet of Things (IoT). [15]	Munnangi Sree Chandana, Dokku Likhitha, Chittiboina Sridevi, Rayapati Akash Chowdary	1. The Arduino IDE andThing Speak for programming the NodeMCU and uploadingsensor data into the cloud.Thing Speak allows fordata analysisand visualization. 2. Usage of a servo motor controlled by NodeMCU to manage the automating fish feeding unit.	1. Aquaponics with IoT maximizes food production, achieving efficiency in water use. 2. Automation and monitoring reduce labor, promoting a responsive farming ecosystem.	1. Risks of disruptions impact system stability. 2. Energy concerns need to be addressed. 3. Proper electronic waste management is a necessity.

III. CONCLUSION

The extensive survey underscores the profound impact of incorporating IoT technology into aquaponics, marking a significant shift towards sustainable farming. The convergence of fish farming and plant cultivation, facilitated by intelligent systems and user-friendly applications, offers a promising avenue for resource efficiency and environmental care. This collaborative strategy not only confronts current challenges but also furnishes a pragmatic response to water scarcity. With empowered farmers leveraging real-time monitoring and remote management tools, the ability to swiftly optimize conditions is evident. Looking forward, the amalgamation of aquaponics and IoT technology foretells a future in farming where efficiency and sustainability harmoniously prevail.

REFERENCES

[1] S. A. Z. Murad, A. Harun, S. N. Mohyar, R. Sapawi, S. Y. Ten, "Design of aquaponics water monitoring system using Arduino microcontroller," 3rd Electronic and Green Materials International Conference 2017 (EGM 2017), 2017.

[2] C. K. Cheong, A. M. K. Iskandar, A. S. Azhar, W. A. F. W. Othman, "Smart Aquaponics System: Design and Implementation using Arduino Microcontroller," International Journal of Research, 2018.

[3] Abhay Dutta, Prayukti Dahal, Rabina Prajapati, Pawan Tamang, Er. Saban Kumar K.C, "IoT based Aquaponics Monitoring System," 1st KEC Conference Proceedings| Volume I, 2018.

[4] Muhammad Fasih Uddin Butt, Raziq Yaqub, Maryam Hammad, Moaz Ahsen, Muneeb Ansir, Nida Zamir, "Implementation of Aquaponics Within IoT Framework," IEEE Southeastcon Huntsville, AL, USA, 2019 .

[5] Haryanto, M Ulum, A F Ibadillah, R Alfita, K Aji, R Rizkyandi, "Smart aquaponic system based Internet of Things (IoT)," IOP Conf. Series: Journal of Physics: Conf. Series 1211 (2019) 012047, 2019.

[6] Yusuke Haruo, Hiroshi Yamamoto, Masao Arakawa, Itsuo Naka, "Development and Evaluation of Environmental /Growth Observation Sensor Network System for Aquaponics,"2020 IEE International Conference on Consumer Electronics (ICCE), 2020.

[7] Maryam Jawadwala, Yogesh Pingle, "Aquaponics for Agriculture using IOT," International Journal of Engineering Research & Technology (IJERT), 2020.

[8] Muhamad Farhan Mohd Pu'ad, Khairul Azami Sidek, Maizirwan Mel, " IoT based water quality monitoring system for aquaponics," Journal

[15] Munnangi Sree Chandana, Dokku Likhitha, Chittiboina Sridevi, Rayapati Akash Chowdary,"Automated Aquaponics Farming using Internet of Things (IoT),"Proceedings of the Second International Conference on Electronics and Renewable Systems (ICEARS-2023), 2023.

Physics: Conference Series, 2020

[9] Jerome Christian C. Egargue, Frederick A. Pacaigue, Raymund Glor F. Galicia, Engr. Glenn V. Magwili, "Development of an Automated Aquaponics System with Hybrid Smart Switching Power Supply," 2020 IEEE REGION 10 CONFERENCE (TENCON), 2020.

[10] Mpho P. Ntulo , Pius. A Owolawi, Temitope Mapayi, Vusi Malele, Gbolahan Aiyetoro, Joseph S. Ojo, "IoT-Based Smart Aquaponics System Using Arduino Uno," Proc. of the International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), 2021.

[11] Shaiz Akhtar Mohammad, Daggumalli Sai NikhilaChowdary, Dr. R. Jebakumar. "An Smart Aquaponic System Using IoT." Journal of Positive School Psychology, 2022 Vol. 6, No. 4, 226-235, 2022

[12] Zahari Abu Bakar, Muhammad Zairil Muhammad Nor, Kamaru Adzha Kadiran, Mohamad Farid Misnan, Maisarah Noorezam, "Smart Plant Monitoring System Using Aquaponics Production Technological with Arduino Development Environment (IDE) and SMS Alert: A Prototype," International Journal of Interactive Mobile Technologies (iJIM), 2022.

[13] Muhammad Al Baihaqi Mat Rani, Izanoordina Ahmad,"Development of IoT Based Aquaponic Monitoring System for Agriculture Application",Journal of Engineering Technology Vol. 10(1), 2022

[14] Manjula H J, andhini K R, Dr.Rashmi S Bhaskar, Namratha S, "IOT BASED AQUAPONICS MONITORING SYSTEM,"International Journal of Creative Research Thoughts (IJCRT) | Volume 11, 2023.