EMBRY-RIDDLE Aeronautical University

Mechanical Engineering

AEROPONIC SYSTEM OPTIMIZATION FOR FUTURE SUSTAINABILITY

Student Researcher: Taylor J. Johnson
Faculty Advisor: Rafael Rodriguez, Ph.D.

BACKGROUND

The global population has grown by 6 billion people over the last century and is trending to approach 9.7 billion people by the year 2050 (Figure 1). Of the 3% of fresh water on Earth, agriculture accounts for 70% of global fresh water usage. Technology must be developed to accommodate for the increase of food production to meet the demand of the growing global population and the resultant increase in water usage (Figure 2).

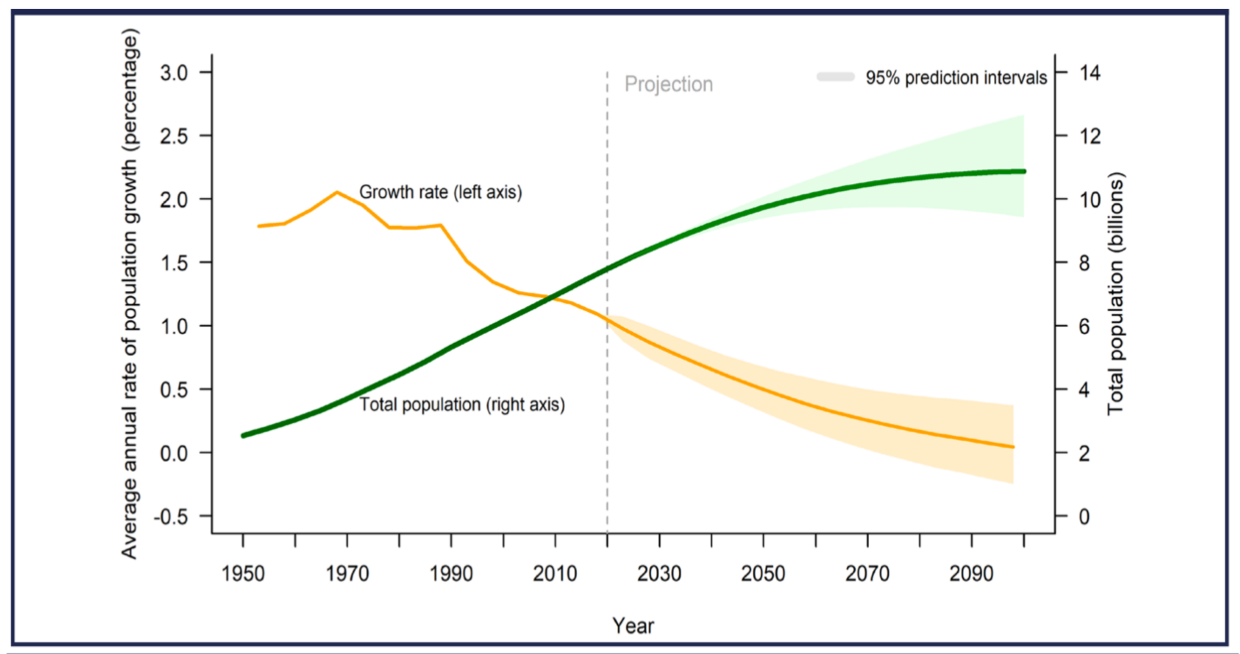

Figure 1. United Nations population growth rate and projection estimate for global population with 95% medium-variant prediction intervals (United Nations, 2019).

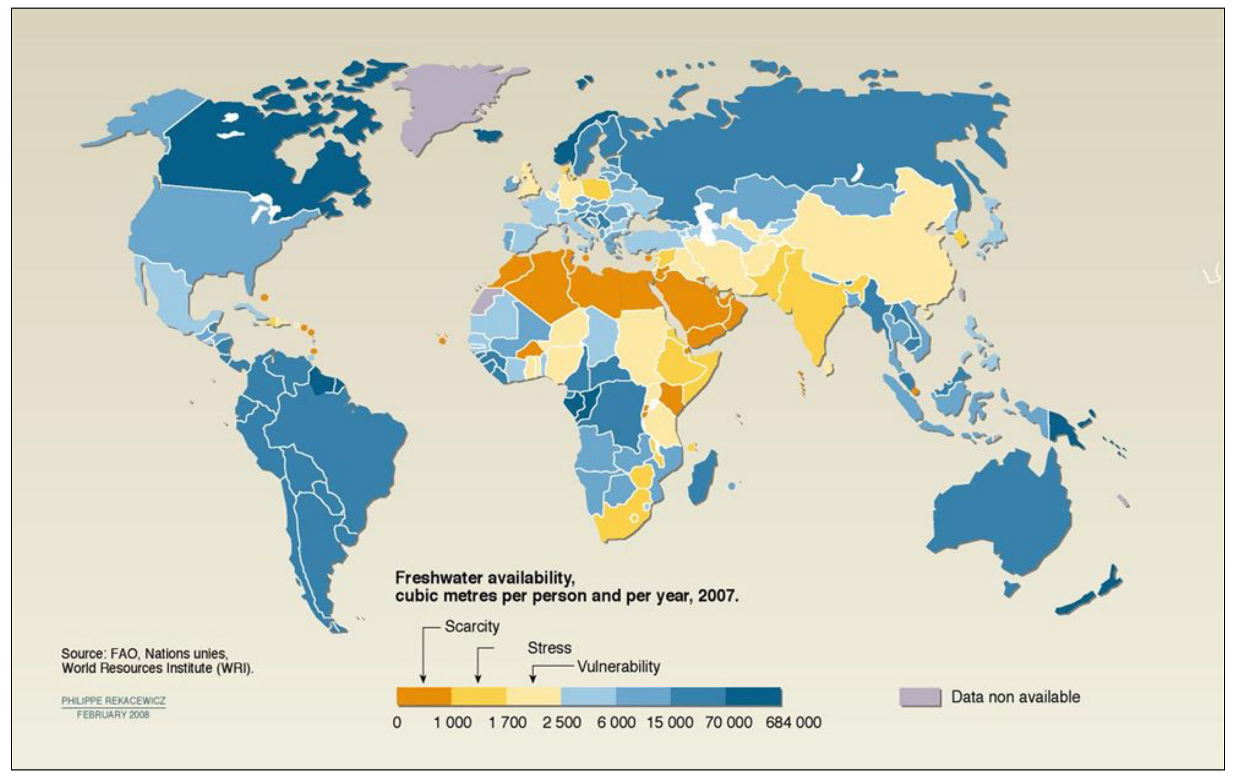

Figure 2. Fresh water availability per person per country (United Nations Environmental Programme, 2007).

AEROPONICS

Aeroponic technology is a water-efficient agricultural technique that suspends plant roots in air within a controlled chamber and supplies atomized droplets of a water-nutrient solution directly to the roots. Aeroponic systems can grow more crops annually due to minimized losses from poor environmental conditions and pests with additional benefit to the environment through elimination of harmful pesticides and herbicides, as well a significant reduction in greenhouse gas emissions from traditional techniques (Lakhiar et al. 2018; Benke et al., 2017; Tunio et al., 2021).

	Hydroponics	Aquaponics	Aeroponics
Root Medium	Water-nutrient solution pumped through closed loop system	Water with nutrients provided from organic waste	Air with water-nutrient solution supplied via atomized droplets
Water Use Efficiency	Approximately 75%	Approximately 80%	Approximately 95%

Table 1. Comparison between vertical farming technologies (Lakhiar, 2018; AlShrouf, 2017).

ABSTRACT

In response to the increasing demand on fresh water usage from an increasing global population, aeroponic systems, which reduce agricultural water usage by over 90%, are a promising solution to supply an increasing quantity of crops while simultaneously using less water. This study intends to determine the optimal droplet size for absorption of the nutrient solution to the roots of butter head lettuce within an aeroponic system under controlled conditions. Further, this study intends to determine how effectively the optimal conditions for one variety of lettuce can be applied to grow other types of lettuce. This research will advance the implementation of a more efficient and sustainable methodology for using water in agriculture. The impacts of this technology have the potential to develop into reliable food sources in arid and urban regions as well as future space applications.

PROJECTED TIMELINE

	Significant Dates	Critical Path
April 2022	April 12th – ERAU Sustainability Conference April 14th – Discovery Day Symposium	Test microcontroller and system sensors Begin calculations for droplet atomization Test soil-less seedling growth environment Test lettuce growth conditions
May 2022/ July 2022	N.A.	Integrate sensors into circuit and test sensor suite Verify sensor function and power draw Develop aeroponic system monitoring platform Test monitoring platform with real time sensor data
August 2022	N.A.	Assemble aeroponic system Cultivate seedlings before start of first test
September 2022	September 5th – begin first aeroponic test	Perform last minute system checks Collect data and monitor system
October 2022	October 14th – cultivate seedlings for test October 17th – end of first aeroponic test October 19th – begin second aeroponic test	Collect data and monitor system Conduct aeroponic system check and perform maintenance
November 2022	November 27th – cultivate seedlings for test November 30th – end second aeroponic test TBD – Fall Student Research Symposium	Collect data and monitor system Conduct aeroponic system check and perform maintenance Analyze collected data from first test
December 2022	December 2nd – begin third aeroponic test	Collect data and monitor system Conduct aeroponic system check and perform maintenance Analyze collected data from second test
January 2023	January 11th –cultivate seedlings for test January 13th – end of third aeroponic test January 15th – begin fourth aeroponic test	Collect data and monitor system Conduct aeroponic system check and perform maintenance Analyze collected data from third test
February 2023	February 25th – begin cultivating seedlings for potential fifth aeroponic test February 27th – end of fourth aeroponic test	Collect data and monitor system Conduct aeroponic system check and perform maintenance Analyze collected data from fourth test
March 2023	March 1st – last possible start date for potential fifth aeroponic test	Collect data and monitor system Conduct aeroponic system check and perform maintenance
April 2023	April 12th – end of potential fifth aeroponic test TBD – Discovery Day Student Research Symposium TBD – Thesis Defense	Finalize data analysis Conclude research findings report Thesis Defense Disseminate research Complete post-assessment deliverable

Table 2. Approximate research timeline.

ACKNOWLEDGMENTS

The knowledge and experience contributed to the research by Dr. Rafael Rodriguez and Dr. Marc Compere are invaluable. This study could not succeed without their insight and advisement.

METHODS

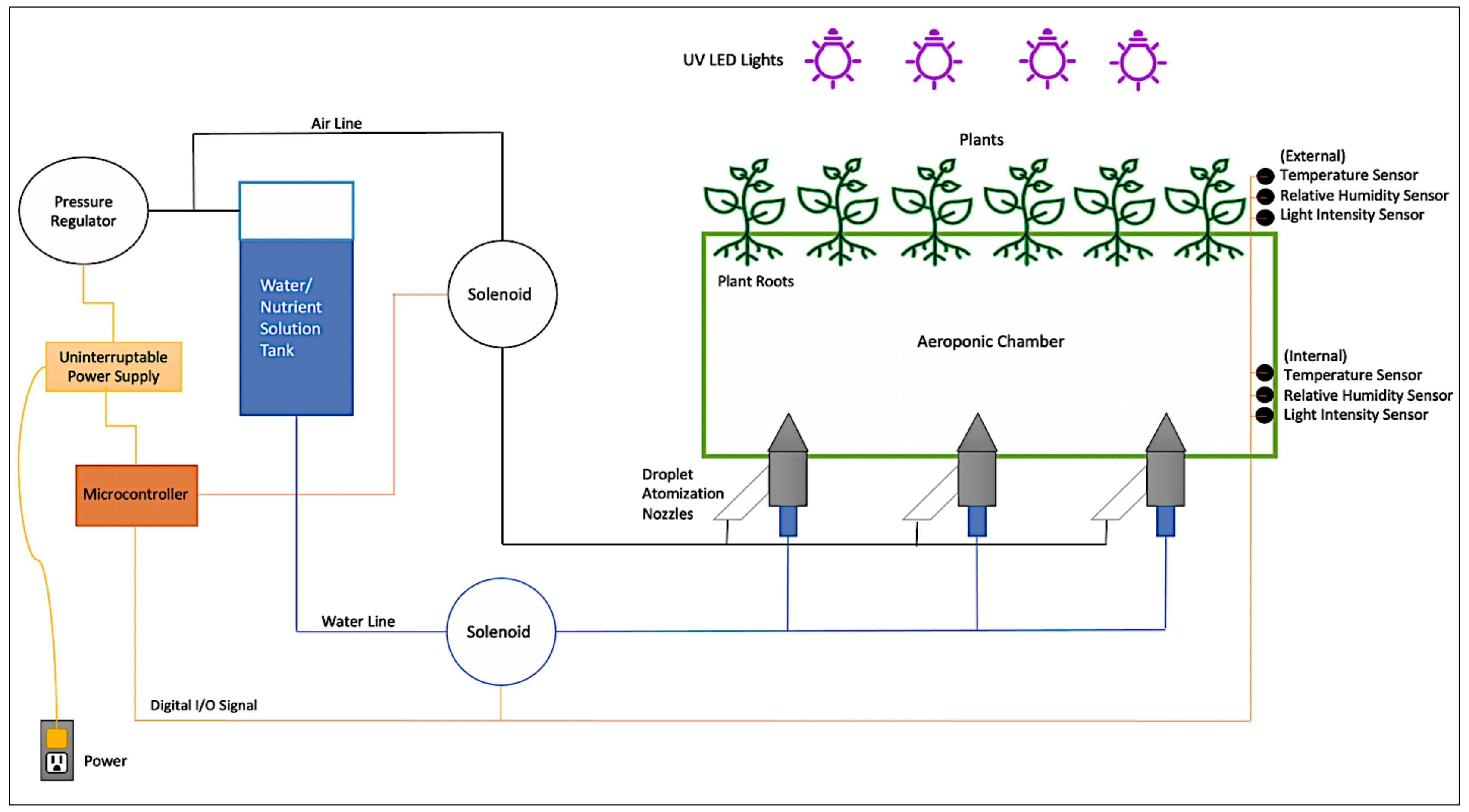

Figure 3. Schematic for experimental aeroponic chamber.

Four aeroponic chambers will be simultaneously tested in an indoor, controlled environment with a consistent nutrient solution atomized into four different droplet sizes ranging from 30 to 100 microns per test environment. The nutrient solution will be monitored with pH and electroconductivity sensors. Temperature, relative humidity, and light intensity, will be recorded above and below the surface of each aeroponic chamber. A microcontroller will regulate the intervals at which the nutrient solution is supplied to the roots and communicate the real time status of the system, including sensor data from the aeroponic chambers, to an online monitoring platform to ensure continuity in the system. Lettuce will be used for testing due to the relatively brief growth time from seedling to maturity of 30 to 45 days. Lettuce grown in the aeroponic system will be compared to a control group of soil-grown lettuce. Performance metrics will be based on mass of the crop yield, plant width, length, and stem diameter, number of leaves, number of roots, root diameter, and water usage.

REFERENCES

AlShrouf, A. (2017). Hydroponics, aeroponic and aquaponic as compared with conventional farming. American Academic Scientific Research Journal for Engineering, Technology, and Sciences, 27(1), 247-255.

Anderson, T. S., De Villiers, D., & Timmons, M. B. (2017). Growth and tissue elemental composition response of butterhead lettuce (Lactuca sativa, cv. Flandria) to hydroponic and aquaponic conditions. Horticulturae, 3(3), 43.

Anderson, T. S., Martini, M. R., De Villiers, D., & Timmons, M. B. (2017). Growth and tissue elemental composition response of butterhead lettuce (Lactuca sativa, cv. Flandria) to hydroponic conditions at different pH and alkalinity. Horticulturae, 3(3), 41.

Benke, K., Tomkins, B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. Sustainability: Science, Practice and Policy, 13(1), 12-26, DOI: 10.1080/15487733.2017.1394054

Ganivet, E. (2019). Growth in human population and consumption both need to be addressed to reach an ecologically sustainable future. Environment, Development and Sustainability, 22(6), 4979-4998. https://doi.org/10.1007/s10668-019-00446-w

Lakhiar, I.A., Gao, J., Syed, T.N., Chandio, F.A., Buttar, N.A. (2018a). Modern plant cultivation technologies in agriculture under controlled environment: a review on aeroponics. Journal of Plant Interactions, 13(1), 338-352. DOI: 10.1080/17429145.2018.1472308

Lakhiar, I. A., Jianmin, G., Syed, T. N., Chandio, F. A., Buttar, N. A., & Qureshi, W. A. (2018b). Monitoring and control systems in agriculture using intelligent sensor techniques: A review of the aeroponic system. Journal of Sensors, 2018.

Lakhiar, I. A., Gao, J., Syed, T. N., Chandio, F. A., Tunio, M. H., Ahmad, F., & Solangi, K. A. (2020). Overview of the aeroponic agriculture–An emerging technology for global food security. International Journal of Agricultural and Biological Engineering, 13(1), 1-10.

Rana, M. K. (2017). Vegetable crop science. CRC Press, 169-182.

Salazar, J. D. R., Candelo-Becerra, J., & Velasco, F. E. H. (2020). Growing arugula plants using aeroponic culture with an automated irrigation system. International Journal of Agricultural and Biological Engineering, 13(3), 52-56. http://dx.doi.org/10.25165/j.ijabe.20201303.5194

Shiklomanov, I.A. (2000) Appraisal and Assessment of World Water Resources, Water International, 25(1), 11-32, DOI: 10.1080/02508060008686794

Tunio, M. H., Gao, J., Lakhiar, I. A., Solangi, K. A., Qureshi, W. A., Shaikh, S. A., & Chen, J. (2021). Influence of Atomization Nozzles and Spraying Intervals on Growth, Biomass Yield, and Nutrient Uptake of Butter-Head Lettuce under Aeroponics System. Agronomy 2021, 11, 97.

United Nations (2019). How certain are the United Nations global population projections? Department of Economic and Social Affairs, Population Facts, 2019(6).

United Nations Environmental Programme (2007). Freshwater availability, cubic meters per person per year, 2007.