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).

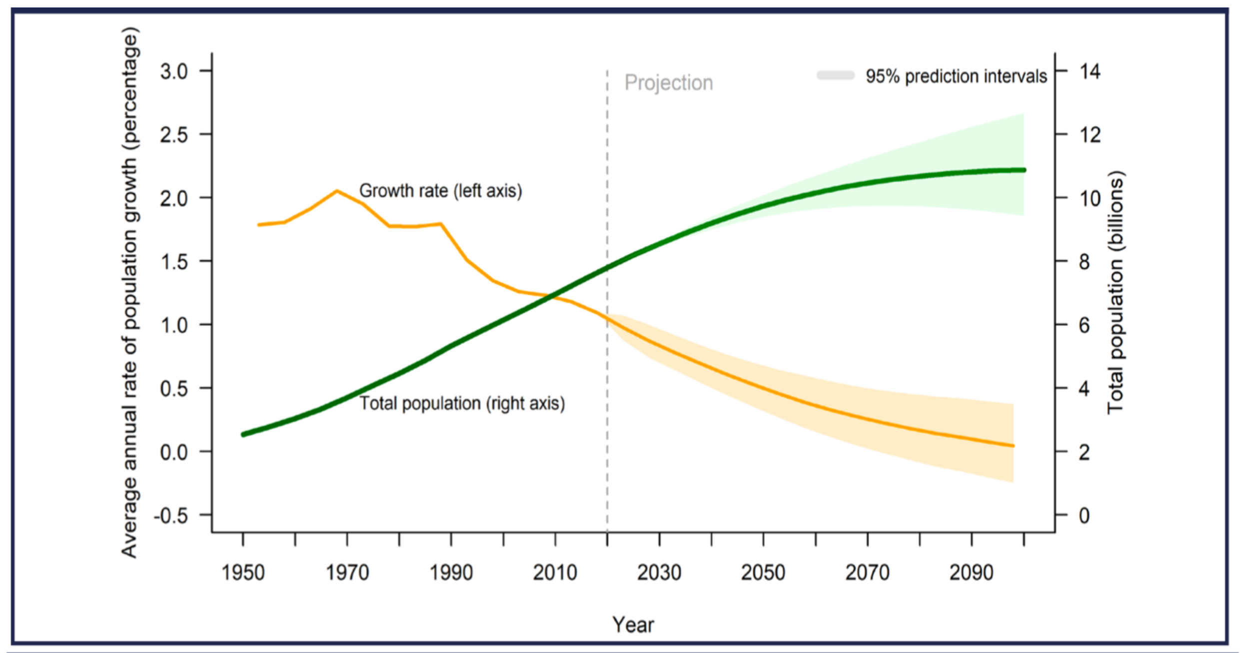

Figure 1. United Nations population growth rate and projection estimate for global population with 95% medium-variant prediction intervals (United Nations, 2019).

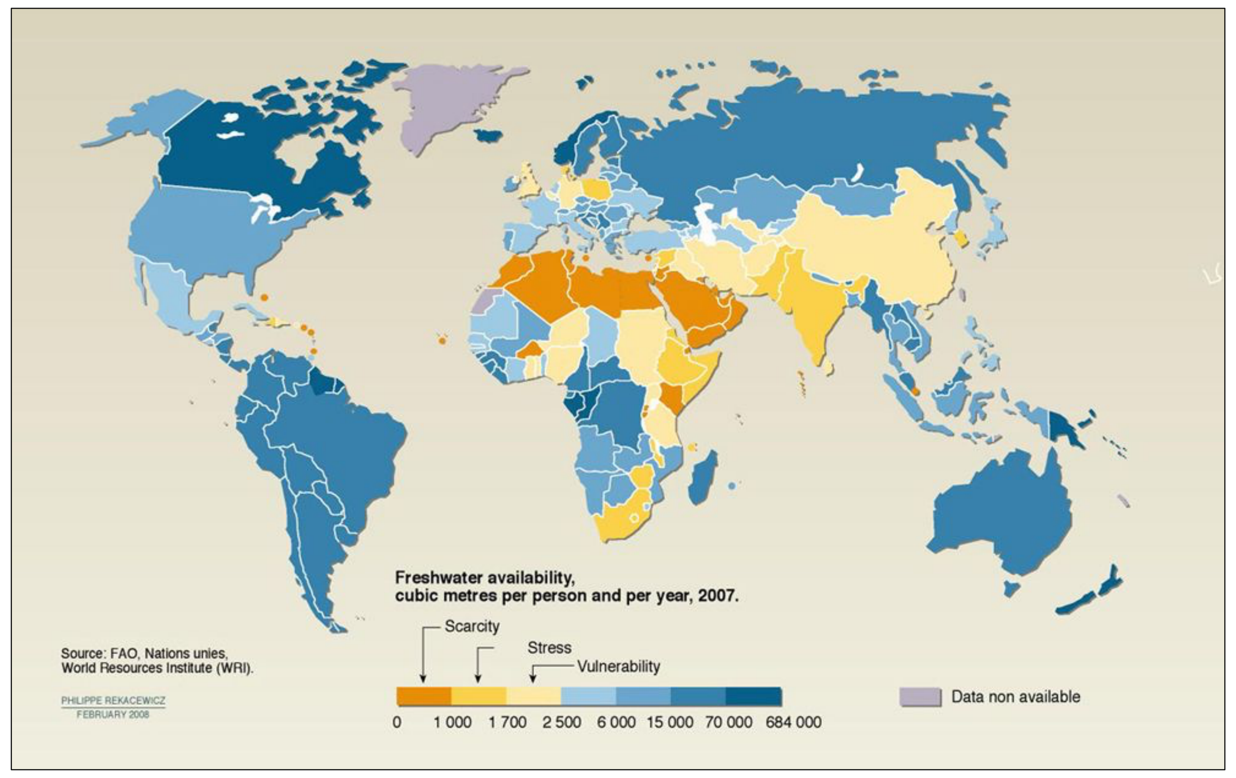

Figure 2. Fresh water availability per person per country (United Nations Environmental Programme, 2007).

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.

CAD MODEL

Dimensions (L 50” x W 24” x H 96”)

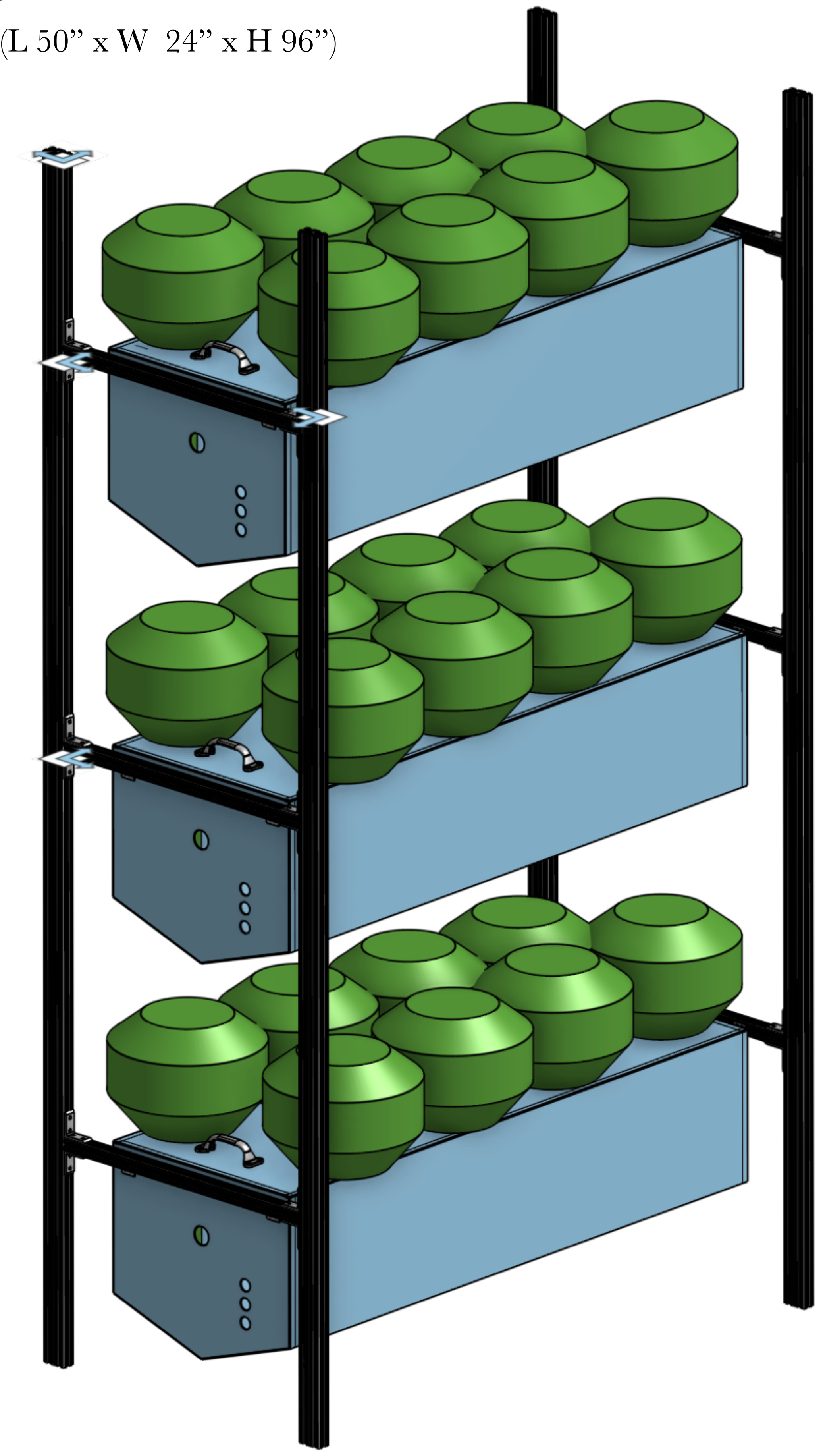

Figure 3. CAD model of experimental design.

METHODS

Test	Variables
#1 – Determine optimal droplet size from range by comparing aeroponic growth results to soil growth results	Chamber 1: 10 μm Chamber 2: 28 μm Chamber 3: 46 μm Chamber 4: 64 μm Chamber 5: 82 μm, Chamber 6: 100 μm
#2 – Verify optimal droplet size	Chamber 1 & 2: optimal size from Test #1 Chamber 3 & 4: second best droplet size from Test #1 Chamber 5 & 6: third best droplet size from Test #1
#3 – Compare optimal droplet size transference	Chamber 1: original lettuce (butterhead) Chamber 2-6: variety of lettuce

Table 1. Test plan for experimental aeroponic chambers.

Six aeroponic chambers will be simultaneously tested in an indoor, controlled environment with a consistent nutrient solution atomized into six different droplet sizes ranging from 10 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.

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M.S.M.E. Mechanical Systems Thesis Track