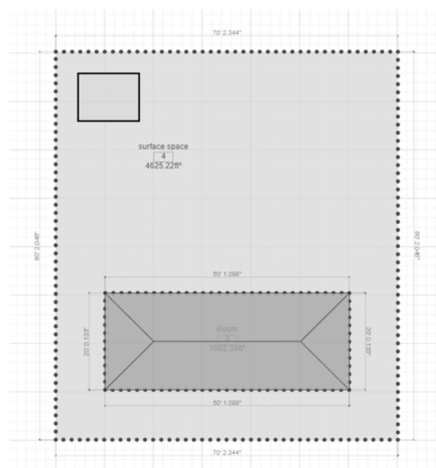
Aquifer to Harvest: Integrating Rainwater Harvesting, Hydroponic and Hydrogel Film Cultivation System and AI-driven Data Monitoring for Sustainable Futures

Juliat Delgado, Nouh Sepulveda, Trina Duong Advisor: Dr Jessica Kuang
Jdadam111@gmail.com, njames5001@gmail.com , trinaduong97@gmail.com
Oxnard College, Oxnard CA

Abstract: Through the strategic implementation of rainwater harvesting systems, and hydroponic and hydrogel soilless gardening techniques, augmented by an AI-driven data monitoring system, we aim to address pressing issues of water scarcity and food insecurity. This integrated approach not only mitigates the strain on traditional water resources but also fosters environmentally sustainable solutions, and paves the way towards a more resilient and food-secure future.

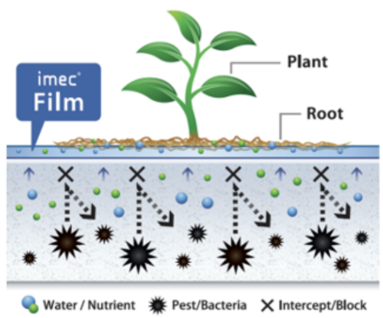
The foundation of sustainability begins within our homes. Our research represents a framework for sustainable water resource management and advocates for the integration of rainwater harvesting systems into everyday households while integrating it into hydroponic and hydrogel agricultural practices. This approach conserves water and fosters resilient communities by building accessible and cost-effective pathways toward a self-sustained system. A rainwater harvesting system can easily be affordable, only requiring; a roof, a gutter, a filter, a barrel or tank, UPVC pipes, an overflow mechanism, and an optional water level indicator. One-inch rain will collect 623 gallons from a 1,000 square foot roof (1). Rainwater collection is legal in the US and is incentivized based on the state one resides in. With this information, this system is not only sustainable, but it could also become a viable economic boon for property owners. A 6000-gallon water tank with a 4-meter diameter occupies only approximately 135 sq ft, which should be more than enough to sustain the hydroponic and IMEC (Intelligent Membrane Culture) hydrogel cultivation system. The image labeled Figure 1, illustrates that with a total surface area of 4625 sq ft, and a 1000 sq ft house along with a rainwater collection tank occupying 135 sq ft in the top left corner, there remains ample space to accommodate our hydrogel and hydroponic system.



(Figure 1 illustrates how much area a 6000-gallon tank will occupy)

Innovative agricultural techniques such as IMEC hydrogel offer a transformative solution to the challenges facing traditional farming methods, promising unparalleled efficiency in water usage, significant reductions in waste, and the ability to cultivate crops in any environment. IMEC uses a polymeric sheet that expands and retains water within its structure without dissolving.

Additionally, IMEC results in a 90% decrease in nutritional waste compared to its soil counterpart (2). Using this method, agriculture sites can be applied to virtually any surface, even on barren land or concrete (3). This technology's versatility allows cultivation even in barren areas and contaminated soils, making it suitable for environments facing land constraints and environmental challenges.



(Figure 2 illustrates the mechanism of hydrogel film)

In addition to the IMEC hydrogel cultivation system, the integration of hydroponic techniques further enhances the sustainability and efficiency of our agricultural approach. Hydroponic systems, which involve growing plants in nutrient-rich water without soil, offer several advantages, including optimized water usage, accelerated plant growth, and reduced environmental impact. By utilizing vertical farming techniques and compact hydroponic setups, we can maximize space utilization and cultivate crops in areas where traditional agriculture may not be feasible. This flexibility makes hydroponics an invaluable component of our integrated approach to sustainable agriculture, enabling us to address food insecurity and water scarcity while promoting environmental stewardship and community resilience. In the article "AI-Driven Pheno-Parenting" by A. J. Hati and R. R. (2023), the innovative real-time monitoring and feedback system, smart resource management, AI-driven pheno-parenting suggestions and GDI (Growth Development Index) that was proposed in the framework aims to enhance plant care and optimize resource utilization (4). By utilizing cameras and deep learning algorithms, we can have this system continuously monitor plant growth, health, and production in both hydroponic and IMEC hydrogel film farming. Receiving real-time feedback on the collected data will allow us to make timely adjustments to the nutrient levels, lighting conditions, and other environmental factors. The utilization of a DNN (Deep Neural Network) based on YOLO V3 for real-time plant monitoring exemplifies the integration of cutting-edge technology into agricultural practices, enabling homesteaders to receive immediate feedback and assistance in plant care. This system provides pheno-parenting suggestions based on plant phenotypic characteristics and growth data. These suggestions will guide us in making informed decisions regarding plant care, disease prevention, and yield optimization. By leveraging artificial intelligence and machine learning, this framework will empower homesteaders with actionable insights to improve overall crop management and productivity. Furthermore, the introduction of the GDI metric provides a novel way to evaluate plant performance and resource utilization efficiency. By incorporating these advancements into our sustainable homestead agriculture system, we highlight the potential for technology-driven solutions to enhance sustainability, productivity, and resilience in small-scale farming operations. This integrated approach aligns with our goal of fostering environmentally conscious and resource-efficient agricultural practices for a more sustainable future.

Work Cited

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4. A. J. Hati and R. R. Singh, "AI-Driven Pheno-Parenting: A Deep Learning Based Plant Phenotyping Trait Analysis Model on a Novel Soilless Farming Dataset," in IEEE Access, vol. 11, pp. 35298-35314, 2023, doi: 10.1109/ACCESS.2023.3265195. keywords: {Computer vision;Agriculture;Hydroponics;Farming;Computational modeling;Analytical models;Plants (biology);Deep learning;Computer vision;deep learning;hydroponic farming;life cycle data analysis;pheno-parenting;phenotyping},