



Minimum Viable Product Documentation
MVP- Dutch Bucket Hydroponic System
UDS Living Lab



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1 Overview

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1.1 Abstract

The Dutch bucket hydroponics system represents a low-cost, sustainable innovation for vegetable production in urban and peri-urban settings. Developed using locally available materials such as paint containers, PVC pipes, valves, and rice husk media, the system operates on a recirculating water cycle that minimizes resource use while ensuring consistent crop growth. Its modular design allows scalability, making it suitable for households, schools, and agripreneurs seeking efficient food production solutions. Experimental trials in UDS LL, Tamale demonstrated successful cultivation of tomatoes, peppers, and watermelon, highlighting the system's adaptability to diverse crops. The integration of carbonized rice husk valorizes agricultural waste, aligning the model with circular economy principles.

Cost analysis indicates an initial investment of GHS 5,351, covering both materials and tools, with operating expenses of GHS 75 per tomato cycle. Revenue from tomato sales per cycle averages GHS 250, yielding a net profit of GHS 175 and a benefit-cost ratio of 3.33. Although the payback period is approximately 31 cycles, the reusability of tools and durability of components enhance long-term affordability. Beyond profitability, the system addresses critical challenges of land scarcity, water efficiency, and food security in Ghana's urban centers. Its potential for replication and training further strengthens its role as a catalyst for sustainable agribusiness. The Dutch bucket hydroponics system thus offers a practical pathway to resilient food production, combining innovation, circular practices, and economic viability.

1.2 Photo



Figure 1: Design of a Dutch bucket system 1

1.3 Motivation and challenges addressed

The Dutch bucket hydroponics system was designed to respond to pressing urban and peri-urban challenges. Rapid urbanization, limited land availability, and increasing water scarcity constrain traditional vegetable production. By repurposing locally available materials, paint containers, PVC pipes, valves, and fittings the system embodies circular innovation, reducing costs while promoting sustainability. The use of carbonized rice husk and road chipping materials as growth media not only diverts agricultural waste from disposal but also enhances soil-less cultivation, aligning with resource efficiency and climate-smart practices. This technology directly supports household and community food security by enabling vegetable production in small spaces such as courtyards, rooftops, and peri-urban plots. It reduces

dependence on rain-fed agriculture, offering resilience against erratic rainfall patterns common in Northern Ghana. Moreover, the system minimizes water use through recirculation, addressing Tamale's recurrent water shortages.

1.4 Feedback process

Over the two-year experimentation with the Dutch bucket hydroponics system, adoption among local farmers has not yet occurred. However, the process has provided valuable lessons that guided continuous refinement of the technology. Initially, the system relied on an overhead container supplying nutrient solution through pipes and valves into the paint buckets containing plants. This design faced significant challenges. Wind action often displaced the nutrient solution, leaving plants deprived, while direct contact with the solution sometimes caused plant corrosion and death, resulting in low survival rates. Additionally, accurate preparation of nutrient mixes using the Hydrobuddy software proved difficult, limiting consistency in plant nutrition. In response to these challenges, the team adapted the system by applying granular fertilizer directly beneath transplants and allowing only water to drip into the media. This modification improved plant survival and reduced nutrient wastage. The use of rice husk-based media continued to support root development while maintaining water efficiency. Through these iterative adjustments, the system has successfully supported the growth of tomatoes, peppers, and watermelon, demonstrating its potential for small-space vegetable production. While farmer adoption remains a challenge, the feedback process has strengthened operational knowledge, highlighted practical limitations, and informed more resilient design choices. These insights provide a foundation for future improvements and for tailoring the system to local conditions in Tamale and beyond.

2 Implementation

2.1 MVP Design

The Dutch bucket hydroponics system developed in Tamale is a compact, resource-efficient design tailored for urban and peri-urban vegetable production. The system is constructed using locally available materials, including paint containers serving as planting buckets, PVC pipes and fittings for water distribution, and simple valves to regulate flow. The growth media is composed of carbonized rice husk and road chippings, which provide aeration, retain moisture, and recycle agricultural waste into productive use. In its final outlook, the system operates through a drip irrigation mechanism where water is supplied from a reservoir and distributed evenly into each bucket and collected in a sump what is manually transferred back to the supplied reservoir on a daily basis. Granular fertilizer is placed beneath the transplants once or twice in the growth circle, ensuring steady nutrient availability directly at the root zone. The water drips onto the media, dissolving nutrients gradually and maintaining optimal moisture for plant growth. This approach reduces complexity of relying on sophisticated software in calculating nutrient mixes and solution preparations while improving plant survival and productivity. The design has proven effective in cultivating tomatoes, peppers, and watermelon, demonstrating its versatility across different crops. Compact and modular, the system can be installed in small spaces such as courtyards, or peri-urban plots, making it suitable for households and communities with limited land and water resources. By combining local materials, waste valorization, and efficient water use, the final MVP design offers a practical pathway for sustainable urban agriculture in Tamale.

2.2 Operations

The Dutch bucket hydroponics system operates through a simple recirculating cycle. Water from the reservoir drips into each planting bucket, nourishing the crops before draining into a sump. From the sump, the water is pumped back into the reservoir, allowing the cycle to continue with minimal waste. This closed-loop design ensures that moisture and nutrients remain available to the plants while reducing

overall water use. Occasional replenishment is required to compensate for losses through leakages and evapotranspiration, typically about twice a week during the rainy season and three to four times weekly in the dry season. By combining drip irrigation with recirculation, the system maintains consistent hydration, supports healthy crop growth, and optimizes resource use, making it well-suited for vegetable production in urban and peri-urban settings where space and water are limited.

2.3 Bill of materials

Item	Quantity*	Unit cost (GHS)	Total cost (GHS)
Blue containers with white lead	9	10	90
1 inch Air valve	4	20	80
1 inch burns	2	5	10
1 inch end caps	4	5	20
1 inch valve suckers	2	3	6
1 inch T	3	5	15
1 inch pipe	1	80	80
1 inch tank connector	2	30	60
Table	1	1000	1000
Tarpaulin	1	250	250
100 liter bucket	2	150	300
Road chippings (kg)	5	150	750
Carbonized rice husk (kg)	10	100	1000
Total			3661

Table 1: Bill of materials

2.4 Tools required

Item	Quantity	Unit cost (GHS)	Total cost(GHS)
Hack saw	1	15	15
Glue small size	1	30	30
Shifting Pliers	2	45	90
Hammer	1	45	45
Hole saw with drill bits	1	1500	1500
Total			1690

Table 2: Tools required

3 Economics

3.1 Business model

The Dutch bucket hydroponics system provides a foundation for a sustainable agribusiness in Tamale. The final design, built from locally available materials and operating on a recirculating water cycle, demonstrates reliable production of tomatoes, peppers, and watermelon in small spaces. This creates opportunities for commercialization through three main pathways. First, the system itself can be marketed as a low-cost kit for households, schools, and urban farmers, offering a practical solution for food production in space and water-constrained environments. Second, entrepreneurs can establish urban farming enterprises, using the system to produce high-value vegetables for local markets, restaurants, and institutions, ensuring consistent supply even in dry seasons. Third, the model supports training and services, where knowledge gained from experimentation is packaged into workshops, consultancy, and maintenance services for adopters. Revenue streams therefore combine sales of hydroponic kits, produce marketing, and capacity-building services. By leveraging circular practices such as rice husk valorization and water efficiency, the business model aligns with sustainability goals while addressing food security challenges in Northern Ghana.

4 Iterative Optimization

4.1 SWOT analysis



Figure 2: SWOT – UDS LL – Dutch bucket system

Strengths

- Built with locally available materials (paint containers, PVC pipes, valves)
- Circular design valorizes rice husk waste into productive growing media
- Water-efficient recirculating system suitable for areas with limited water
- Compact and modular, enabling production in small spaces
- Proven success with tomatoes, peppers, and watermelon

Weaknesses

- Limited farmer adoption so far, requiring more awareness and training
- Dependence on manual replenishment of water, which may be labor-intensive
- Simplified fertilizer application reduces precision in nutrient management
- Durability of improvised materials may be lower compared to commercial systems.

Opportunities

- Rising demand for fresh vegetables in urban centers like Tamale
- Potential for agribusiness models: kit sales, produce marketing, and training services
- Alignment with sustainability and climate-smart agriculture policies
- Can be scaled for schools, institutions, and community gardens
- Opportunity to integrate with renewable energy (e.g., solar pumps) for efficiency.

Threats

- Competition from conventional farming and imported hydroponic systems
- Risk of water shortages or rising costs affecting system operation
- Farmers' reluctance to adopt unfamiliar technology without clear economic benefits
- Possible wear-and-tear of low-cost components leading to maintenance challenges

4.2 Optimization

The Dutch bucket hydroponics can be optimized by strengthening nutrient management. Instead of relying on complex software calculations, farmers can use pre-formulated nutrient mixes tailored to crops such as tomatoes, peppers, and watermelon. Incorporating slow-release or coated granular fertilizers ensures a steady supply of nutrients directly at the root zone, reducing plant stress and improving yields.

Water efficiency can also be enhanced by improving the recirculating cycle. Sealing leaks and using durable fittings will minimize water loss, while simple sensors can be introduced to monitor water levels and automate replenishment. In Tamale's dry season, integrating solar-powered pumps would provide a sustainable and cost-effective way to maintain circulation without increasing energy costs.

Design improvements further strengthen the system's resilience. Using UV-resistant buckets or barrels extends durability, while adding protective covers around drip emitters prevents wind from displacing water. Modular construction allows farmers to start small and expand gradually, making adoption more accessible.

Crop performance can be optimized by adjusting plant spacing and bucket arrangement to maximize light exposure and airflow. Rotating crops seasonally not only maintains the health of the rice husk media but also diversifies income streams.

Finally, farmer training and demonstration farms are critical to adoption. By showcasing profitability, water savings, and crop quality, the system becomes more attractive to households, schools, and agripreneurs. These optimizations transform the Dutch bucket hydroponics system from an experimental prototype into a reliable, scalable model for sustainable urban agriculture.

4.3 Threat mitigation

To mitigate competition from conventional farming and imported hydroponic systems, the Dutch bucket design must emphasize its unique strengths. Demonstration farms and pilot projects can showcase its affordability, reliance on local materials, and water efficiency. By proving profitability and crop quality, the system can position itself as a practical alternative that meets the needs of urban and peri-urban farmers.

Water shortages can be addressed through resource-efficient practices. Integrating rainwater harvesting and storage tanks provides a supplementary supply. The recirculating design already minimizes water use, but farmer training on efficient water management will further strengthen resilience during dry seasons.

Farmer reluctance to adopt unfamiliar technology can be overcome through capacity building. Hands-on training, workshops, and peer-to-peer learning will build confidence, while early adopters can serve as champions to share success stories. Simplifying the operation of the system, such as using granular fertilizer instead of complex nutrient mixes, makes it more approachable and user-friendly.

Additionally, the durability of low-cost components can be improved by gradually replacing improvised materials with UV-resistant buckets, quality fittings, and protective covers.

5 Appendix

5.1 Photographs/Documentation



Figure 3: Design of a Dutch bucket system 2



Figure 4: Design of a Dutch bucket system 3



Figure 5: Design of a Dutch bucket system 4