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# WASTE PLASTIC BOTTLES AND PVC SCRAPS INTO LOW-COST, ECO-FRIENDLY HYDROPONIC SYSTEM FOR EFFICIENT LETTUCE PRODUCTION

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## Abstract

*Plastic waste management, limited agricultural space, and the high cost of commercial farming technologies continue to challenge sustainable food production, particularly in urban and community settings. In response to these concerns, this study developed and evaluated a hydroponic lettuce production system using recycled plastic bottles, PVC pipe scraps, and leftover lumber materials. The project aimed to demonstrate how recyclable materials can be converted into useful agricultural resources while promoting sustainable practices and strengthening TVET skills in plumbing and carpentry. The implementation involved collecting and preparing recyclable materials, constructing a hydroponic structure, producing seedlings, cultivating lettuce, monitoring plant growth, and conducting system evaluation with the participation of TVET trainers, faculty experts, industry practitioners, and local farmers. The system was assessed in terms of growth and yield performance, functionality, durability, replicability, environmental impact, cost efficiency, and adaptability and modularity. The results showed that the hydroponic system successfully supported lettuce growth and yield, with performance comparable to commercially produced lettuce. Evaluators also gave favorable ratings across all assessment criteria, indicating that the system was functional, durable, easy to replicate, cost-efficient, and adaptable to different settings. The findings suggest that recyclable materials can be effectively utilized in hydroponic farming and that the system can serve as a practical option for schools, households, urban gardens, and community-based food production initiatives. The study concludes that the recycled-material hydroponic system is a sustainable and accessible approach to vegetable production that supports both environmental conservation and skills development.*

**Keywords:** hydronics, sustainable agriculture, Green TVET practices, recycling, soilless farming, lettuce cultivation.

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# INTRODUCTION

Waste management remains a significant environmental challenge in the Philippines, particularly due to the increasing volume of plastic waste generated daily. According to a report by Moaje (2025) of the Philippine News, the Department of Environmental and Natural Resources (DENR) emphasized that the Philippines remains one of the world's major contributors to plastic waste and continues to face challenges in waste segregation, recovery, and recycling infrastructure. Improper disposal of non-biodegradable waste materials can clog waterways, occupy valuable landfill space, and release harmful substances into the environment, (Mole 2025).

The demand for sustainable practices has grown more and more important in today's globe. An essential part of this shift is the green economy, which places an emphasis on low carbon emissions, resource efficiency, and social inclusion. The Technical Vocational Education and Training (TVET), is crucial to this change because it gives people and communities the skills and information they need.

Growing plants without soil, or hydroponics, has become increasingly popular as a cost-effective and environmentally friendly substitute for conventional farming practices in recent years. Innovative methods that combine recycled materials into hydroponic systems have surfaced to address this problem, providing a more economical and environmentally responsible option.

As noted by Lisnawati et al. (2025), hydroponics utilizing recycled materials provides an economical and environmentally responsible way to repurpose waste products including PVC pipes, plastic bottles, and other post-consumer plastics. By minimizing the demand for new materials and reducing the quantity of waste transported to landfills, this strategy lowers the system's overall carbon footprint. Utilizing recycled materials in hydroponic gardening also contributes to the circular economy, which turns trash into useful resources for growing food.

Furthermore, hydroponics utilizing recycled materials can be very helpful in places where traditional farming resources are rare or inaccessible. Compact designs and vertical growing systems make these hydroponic solutions easily adaptable to small-scale or urban enterprises. In light of global concerns including population growth, climate change, and resource scarcity, hydroponics presents a promising alternative for sustainable food production due to its innovative use of recyclable materials and effective use of water and nutrients.

The objective of the study is to develop and evaluate a hydroponic lettuce production system using recyclable materials such as plastic bottles, plumbing scraps, and carpentry offcuts as a low-cost and sustainable approach to urban agriculture. Specifically, the study aims to design and construct a functional hydroponic system using these recyclable materials, determine the growth and yield performance of lettuce grown in the system, and evaluate its functionality, durability, cost efficiency, environmental impact, and adaptability and replicability. It also seeks to assess the integration of TVET skills in plumbing and carpentry in the development of the system and determine its potential as a practical and sustainable solution for urban and space-limited vegetable production.

# DEVELOPMENT AND IMPLEMENTATION OF THE BEST PRACTICES

**Research Initiative / Objectives**

The study focused on the development of a low-cost and eco-friendly hydroponic system for lettuce production using recycled plastic bottles, PVC pipe scraps, and leftover lumber materials. The project aimed to provide a sustainable alternative food production system suitable for urban gardening, educational institutions, and small-scale farming.

Specifically, the study sought to develop and construct a low-cost hydroponic system utilizing recyclable waste materials, evaluate its functionality and performance in terms of plant growth, yield, and production efficiency, determine its environmental and cost-efficiency benefits compared to conventional hydroponic systems, and assess its adaptability and replicability for schools, households, and small-scale agricultural applications.

The research addressed several environmental and sustainability concerns, including plastic waste pollution, limited farming space, high costs of commercial hydroponic systems, and improper waste disposal practices. Through the utilization of recyclable materials, the project promoted waste reduction, resource conservation, and sustainable agricultural practices.

**Research Design and Methodology**

The study utilized a developmental and descriptive research design focusing on the construction, implementation, and evaluation of a hydroponic system made from recycled materials for lettuce production. The project emphasized the use of locally available and reusable materials to promote sustainable agriculture, reduce environmental waste, and demonstrate that innovative farming technologies can be developed at a lower cost while supporting environmental conservation and urban food production.

The tools and materials used in the study included a mini submersible pump, PVC elbows and scraps, recycled plastic bottles, lumber, nails, coco peat, nutrient solutions, and seedling trays and containers. The construction phase involved the development of a bleacher-type hydroponic structure composed of four levels capable of accommodating 114 recycled plastic bottles used as growing containers for lettuce plants. The system was constructed using recycled plastic bottles, PVC pipe scraps, leftover lumber materials, and basic plumbing and carpentry tools. To protect the crops and maintain suitable growing conditions, a nursery and protective shelter with UV plastic covering and shading materials were installed to minimize the effects of excessive sunlight and heavy rainfall. Lettuce seeds were initially sown in seedling trays containing coco peat and nutrient solution to support germination and seedling development. Prior to use, the coco peat was treated with hydrogen peroxide to regulate acidity and eliminate harmful pathogens.

After 21 days, healthy seedlings were transplanted into the hydroponic system using the recycled bottle containers. Throughout the growing period, regular maintenance was carried out, including replenishing the nutrient solution, monitoring of pH and nutrient concentration (PPM), and observing plant growth and overall health. Insect pests, particularly cutworms and leaf miners were occasionally observed and were manually removed because

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their population was minimal. The lettuce crops were harvested 45 days after transplanting and were marketed through a "Pick and Pay" scheme.

The study employed quantitative and descriptive evaluation research design. The data gathering procedure involved a systematic evaluation of the hydroponic system made from recycled plastic bottles, plumbing scraps, and carpentry offcuts, focusing on system functionality, durability, cost efficiency, environmental impact, adaptability and replicability, as well as growth and yield performance. Growth and yield data were collected quantitatively through measurements of plant height, number of leaves, root length, and overall biomass at harvest, while system functionality was assessed through observation of nutrient and water flow and general plant support. Durability was evaluated by monitoring the condition and stability of the recycled materials throughout the production period, whereas cost efficiency was determined by recording all expenses incurred during construction, maintenance, and operation. Environmental impact was assessed based on the amount of waste materials reused and the reduction of waste generated, and adaptability and replicability were determined through actual implementation and evaluator feedback on ease of construction and use in other similar settings.

As shown in Figure 1, the hydroponic system was developed in the study utilizing recycled plastic bottles, PVC pipe scraps, and plumbing materials for small-scale lettuce production. The multi-level structure was designed to maximize space utilization, promote the reuse of recyclable materials, and provide a low-cost and sustainable approach to urban agriculture and community-based food production.



**Figure 1. Recycled-Material Hydroponic System for Lettuce Production**

Figure 2 shows the lettuce plants at harvest stage grown in the hydroponic system developed from recycled plastic bottles, PVC pipe scraps, and other reusable materials. The healthy growth, dense foliage, and uniform appearance of the plants demonstrate the effectiveness of the system in supporting lettuce production. The figure highlights the potential of recycled-material hydroponics as a low-cost, sustainable, and space-efficient approach to urban agriculture and community-based vegetable production.



Figure 2. Mature Lettuce Grown in the Recycled-Material Hydroponic System

**Partnerships and Collaboration**

The study involved the participation of partner institutions from the academe, farming industry, local farmers, and the local government unit. The collaboration included benchmarking and knowledge-sharing activities that allowed participants to observe the system and exchange ideas for improvement and replication. Overall, these partnerships strengthened institutional linkages, enhanced awareness of sustainable agricultural practices, and supported the potential adoption of the hydroponic system in training centers and farming communities.

**Application and Utilization of Results**

The results of the study were used to promote sustainable agriculture, environmental protection, and community awareness by demonstrating a hydroponic system made from recyclable materials such as plastic bottles, plumbing scraps, and carpentry offcuts. It supported urban gardening and small-scale vegetable production and served as a learning tool for students, farmers, and community members on hydroponic farming and recycling practices. The system was also applied in training sessions, demonstrations, and knowledge-sharing activities to enhance participants' understanding of low-cost and eco-friendly farming methods that can be used in homes, schools, and communities. In addition, it helped strengthen environmental awareness and encouraged waste reduction while promoting sustainable agriculture through activities such as "Pick and Pay" and social media promotion, which increased community interest in hydroponic farming.

**Evaluation Procedure**

The evaluation procedure involved a systematic assessment of the hydroponic system made from recyclable materials such as plastic bottles, plumbing scraps, and carpentry offcuts to determine its effectiveness and sustainability. The system was evaluated based on key criteria, including growth and yield performance of lettuce, system functionality, durability of materials used, cost efficiency,

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environmental impact, and adaptability and replicability. Data on plant growth and yield were collected through actual measurements, while system performance was assessed through observation during the production cycle.





Evaluators composed of TVET trainers, faculty experts, industry practitioners, and local farmers provided ratings and feedback based on set evaluation criteria and observation guides. All quantitative and qualitative data gathered were organized and analyzed using descriptive evaluation techniques to determine the overall performance and practicality of the hydroponic system for sustainable urban agriculture.

As shown in Table 1, the use of multiple instruments and evaluators enhanced the validity and reliability of the study by providing comprehensive assessments of the hydroponic system's performance. This approach enabled the researchers to gather objective data and diverse perspectives regarding its functionality, durability, adaptability, and overall effectiveness.

Table 1. Summary of Research Design and Implementation

| Component | Description |
|---|---|
| Research Design | Experimental |
| Duration | 2 months |
| Key Variables | Functionality, Durability, Replication, Environmental Impact, Cost Efficiency, Mobility, and Adaptability and Replicability, Growth and Yield |
| Tools used | TDS meter, nutrient solution, timer switch, circuit breaker, submersible pump |
| Evaluators | TVET trainers, faculty experts (agriculturist, plumber, carpenter), industry practitioners, local farmers |

# RESULTS AND DISCUSSION

**Key Results and Findings**

The study showed that a hydroponic system made from recycled plastic bottles and PVC scraps can be used effectively for growing lettuce on a small scale. The recycled bottles worked well as planting containers, while the plastic cups provided enough support for root development and nutrient uptake. The lettuce plants grew healthy, and the structure remained stable and durable during use when properly assembled and maintained.

The system was also found to be affordable, easy to build, and suitable for different settings. Because it uses readily available recycled materials, it can be replicated by schools, households, urban gardeners, and small-scale farmers. Its design allows users to expand or modify the setup according to their needs and available space. By reusing plastic waste, the project also helps promote recycling and environmental awareness.

The results of the study demonstrated that the hydroponic system constructed from recycled plastic bottles and PVC scraps was effective for small-scale lettuce production. To assess growth and yield performance, 30 lettuce plants were randomly selected and used as samples for data gathering. The plants exhibited healthy growth, proper root development, and efficient nutrient absorption throughout the growing period. As shown in Table 1, the sampled plants produced an average of 16 leaves, with an average leaf length of 11 cm, root length of 9 cm, and fresh weight of 400 g. These growth and yield measurements are comparable to those commonly observed in commercially produced lettuce, indicating that the recycled-material hydroponic system was able to provide suitable growing conditions for crop development.

Table 2. Growth and Yield of Lettuce

| Parameters | Average |
|---|---|
| No. of leaves | 16 |
| Length of leaves (cm) | 11 |
| Length of roots (cm) | 9 |
| Fresh weight (g) | 400 |

The evaluation results presented in Table 2 indicate that the recycled-material hydroponic system was highly accepted by the 30 evaluators, as reflected in its overall mean rating of 4.96, interpreted as Excellent. Functionality, durability, and replicability each obtained a mean rating of 4.97, showing that the system performed effectively, remained stable during operation, and could be easily reproduced using locally available materials. Environmental impact received a perfect mean rating of 5.00, indicating unanimous agreement among the evaluators regarding the system's contribution to waste reduction and environmental sustainability through the reuse of plastic bottles and PVC scraps. Cost efficiency and adaptability and modularity both received mean ratings of 4.93, suggesting that the system was affordable and could be modified or expanded according to the user's available space and production needs. These findings demonstrate that the hydroponic system not only met its intended purpose of supporting lettuce production but also offered practical, economic, and environmental benefits, making it a suitable option for schools, households, urban gardens, and community-based farming initiatives.

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**Table 3. Evaluation Results of the Recycled-Material Hydroponic System (n = 30)**

| Criteria | Score 1 (Frequency) | Score 2 (Frequency) | Score 3 (Frequency) | Score 4 (Frequency) | Score 5 (Frequency) | Total Respondents | Mean Rating |
|---|---|---|---|---|---|---|---|
| Functionality | 0 | 0 | 0 | 1 | 29 | 30 | 4.97 |
| Durability | 0 | 0 | 0 | 1 | 29 | 30 | 4.97 |
| Replication | 0 | 0 | 0 | 1 | 29 | 30 | 4.97 |
| Environmental Impact | 0 | 0 | 0 | 0 | 30 | 30 | 5.00 |
| Cost Efficiency | 0 | 0 | 0 | 2 | 28 | 30 | 4.93 |
| Adaptability and Modularity | 0 | 0 | 0 | 2 | 28 | 30 | 4.93 |

**Overall Mean Rating: 4.95**

**Interpretation: Excellent**

*Note: The mean rating was computed using a 5-point scale, where 5 is the highest possible score. Thirty (30) respondents, composed of evaluators from various fields, participated in the assessment of the hydroponic system.*

The findings show that recycled plastic bottles, plumbing scraps, and carpentry offcuts can be used successfully in a hydroponic system for growing lettuce. The healthy growth of the plants, together with good root development and nutrient absorption, indicates that these recycled materials were able to provide a suitable environment for plant growth. The stability and durability of the structure during the growing period also suggest that recycled materials can perform effectively as components of a hydroponic system when properly assembled and maintained.

The results also suggest that the system is practical for individuals and groups with limited resources. Since the materials are inexpensive and easy to obtain, the setup can be adopted by schools, households, urban gardeners, and small-scale farmers. Its flexible design allows it to be adjusted or expanded depending on the available space and the needs of the user. In addition, the use of recycled materials helps reduce plastic waste and encourages recycling, making the project beneficial not only for food production but also for environmental sustainability. Overall, the study shows that the system is a useful and affordable option for small-scale hydroponic farming.

The recycled-material hydroponic system developed in this study differs from traditional hydroponic systems mainly in terms of cost, sustainability, and accessibility. Traditional systems use commercially manufactured components such as grow trays, net pots, and nutrient reservoirs, which provide greater durability, uniformity, and production efficiency. In contrast, the recycled-material system uses plastic bottles, plumbing and carpentry scraps, and other recyclable materials, making it a more affordable and environmentally friendly option while still supporting healthy lettuce growth and effective hydroponic cultivation.

The main advantage of the recycled-material system is its affordability and environmental benefit. By using discarded materials, the system reduces construction costs and helps minimize plastic waste. It is also easy to construct and adapt, making it suitable for schools, households, urban gardeners, and small-scale farmers. While regular maintenance may be needed to ensure durability, the results show that the system can be a practical alternative for small-scale hydroponic production and can contribute to sustainable agriculture and community-based food production.

The results of the study are consistent with practices that promote sustainable agriculture and urban gardening. The use of recycled plastic bottles and PVC scraps shows that materials commonly considered waste can be reused for food production. This approach provides a practical option for growing vegetables in areas with limited space and resources.

The study also supports the objectives of Republic Act No. 9003 or the Ecological Solid Waste Management Act of 2000, which encourages recycling and proper waste management. It is likewise aligned with Republic Act No. 8435 or the Agriculture and Fisheries Modernization Act, which promotes the use of appropriate technologies to improve agricultural productivity and sustainability.

Previous studies have shown that hydroponics can be an effective method of growing vegetables because it allows efficient use of water and nutrients. Literature also suggests that recycled materials can be utilized as alternatives to commercial hydroponic components. The findings of this study support these observations, as the recycled-material system was able to sustain lettuce growth while reducing costs and encouraging environmental responsibility.

## CONCLUSION AND RECOMMENDATIONS

The findings of the study showed that the hydroponic system made from recycled plastic bottles and PVC scraps can be used successfully for small-scale lettuce production. The system provided suitable conditions for plant growth, allowing the lettuce to develop healthy roots and absorb nutrients effectively. The materials used in the construction of the system proved to be stable, functional, and suitable for hydroponic cultivation. In addition, the setup was affordable and could be used in various settings such as schools, households, and urban gardens.

The study also demonstrated the value of reusing discarded materials for agricultural purposes. By utilizing recycled plastic bottles, plumbing, and carpentry scraps the system helped reduce construction expenses while promoting the reuse of materials that might otherwise become waste. The favorable feedback from

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evaluators and practitioners suggests that the system can be applied in community-based farming and urban agriculture initiatives. These findings indicate that recycled materials can serve as practical alternatives for hydroponic production while supporting environmental conservation and sustainable food production.

Based on the findings of the study, the recycled-material hydroponic system may be adopted by schools, households, urban gardeners, and small-scale farmers as a low-cost and sustainable method of vegetable production. Educational institutions and community organizations may also utilize the system to promote environmental awareness, recycling practices, and urban agriculture.

Future researchers are encouraged to test the system using other crops to determine its effectiveness for a wider range of vegetables and plants. It is also recommended to improve the planting distance between crops to reduce shading and competition for light, which may further enhance plant growth and yield. Adjustments in the layout and spacing of planting containers may help maximize the use of available space while ensuring adequate sunlight exposure.

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