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Design and Implementation of a Custom Nozzle for Efficient Irrigation System in the Agricultural Faculty of UISU: a Community Service Approach

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ABSTRACT
The Islamic University of North Sumatra (UISU) aims to become increasingly recognized as a top-quality higher education institution, even internationally. This is evident in the ongoing collaborations between the UISU Faculty of Engineering and several educational institutions abroad, particularly in Southeast Asian countries like Thailand and Malaysia. The Faculty of Engineering is currently collaborating with the Saengtham Wittaya School Foundation in Trang, Thailand, for a Sociopreneurship-Based Business Development program for SMSEs in Trang, Thailand. This partnership is a positive step for UISU, as it embodies its vision and mission to expand its reach and become better known internationally. This collaboration is part of the International Mobility of Academics (IMA) program implemented by the ADA Research Center, and is being followed up by the Foundation Saengtham Wittaya School to establish a partnership. This collaboration is expected to benefit all parties, as it discusses many positive aspects for the advancement of education both at home and abroad. The quality and capacity possessed by UISU is believed to be one of the reasons why foreign educational institutions are willing to collaborate with UISU for educational development. The Saengtham Wittaya School Foundation in Thailand chose UISU because it is an Islamic educational institution with a track record of producing high-quality graduates with noble morals, established in 1951. Furthermore, it aims to develop UISU as a higher education institution capable of producing many high-quality individuals in the world of education. The collaboration between UISU and the Saengtham Wittaya School Trang Thailand Foundation will be carried out in the form of collaborative research, community service, journals and development between researchers, institutions, organizations and agencies, including Harapan University Medan, Cendana Polytechnic, Muhammadiyah University of North Sumatra, and the Terrorism Prevention Coordination Forum (FKPT).

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INTRODUCTION

Water is a fundamental resource for agricultural productivity, and efficient irrigation plays a critical role in ensuring sustainable food production. In many developing regions, including

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Indonesia, traditional irrigation practices often result in significant water loss due to leakage, uneven distribution, and poor infrastructure maintenance (Rahmawati et al., 2023). This inefficiency not only increases operational costs for farmers but also reduces crop yields and threatens long-term water sustainability. The design and application of innovative yet low-cost irrigation technologies are therefore essential to support smallholder farmers and academic institutions in promoting sustainable agricultural practices. One practical solution is the development of customized nozzles for irrigation systems. Nozzles are key components that directly influence the uniformity of water distribution, pressure regulation, and overall system efficiency (Kumar & Singh, 2022). Conventional nozzles used in local farming communities often lack durability and adaptability to varying crop conditions. As a result, many farmers continue to rely on manual watering techniques, which are labor-intensive and inefficient. By designing a nozzle tailored to the specific needs of agricultural land within the Faculty of Agriculture, Universitas Islam Sumatera Utara (UISU), this project aims to demonstrate how applied engineering can be integrated into community service to solve real agricultural challenges. This initiative adopts a community service approach, bridging academic research with local community needs. The Faculty of Agriculture UISU has long served as a hub for agricultural education and training, yet its irrigation facilities face limitations in both technology and efficiency. Through participatory design and implementation, the project seeks not only to improve irrigation performance but also to provide a learning model for students, lecturers, and local farmers. Such an approach aligns with Indonesia's national agenda to strengthen higher education's role in Tri Dharma Perguruan Tinggi, particularly in the aspect of community service and empowerment (Suryana & Hidayat, 2021).

The novelty of this study lies in the design and fabrication of a custom nozzle that balances cost-effectiveness, durability, and technical efficiency, while simultaneously empowering local communities through knowledge transfer. By implementing this innovation, the project is expected to reduce water usage, optimize irrigation practices, and enhance crop productivity in a sustainable manner. Furthermore, it highlights how higher education institutions can actively contribute to agricultural development by applying simple but impactful engineering solutions. Plant watering is a crucial aspect of agricultural and plantation cultivation. Uneven watering patterns or excessive water use often hinder crop productivity. Many farmers and gardeners still use manual watering methods, which are inefficient in terms of time, effort, and water use. As a component of an irrigation system, nozzles play a role in regulating water pressure and distribution patterns to ensure a more even distribution and meet plant needs. However, the availability of nozzles with optimal designs and affordable prices remains a challenge for small- and medium-scale farmers. Therefore, innovation in nozzle design is needed to improve irrigation efficiency and support sustainable agricultural practices.

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Figure 1. Opening Ceremony of Community Service

This community service activity aims to:

1. Design and manufacture efficient and easy to use plant watering nozzles farmer.
2. Increase farmers' understanding of the importance of using effective watering tools to optimize plant growth.
3. Reduce water waste through a more controlled irrigation system.

The benefits expected from this activity include:

1. Helping farmers manage crop irrigation more efficiently.
2. Increase agricultural yields with more even watering.
3. Supporting water conservation efforts in the agricultural sector.
4. Providing innovative solutions that can be widely adopted among farmers.

With this activity, it is hoped that farmers can more easily access simple but effective technology to support the growth of their crops, so that agricultural productivity can increase sustainably.

Literature Review

Irrigation Efficiency and Agricultural Sustainability

Efficient irrigation is a cornerstone of sustainable agriculture, particularly in regions where water scarcity and climate variability pose challenges to crop productivity. Traditional irrigation methods, such as surface flooding, often lead to substantial water losses through evaporation, percolation, and runoff (Ali et al., 2021). Studies have shown that the adoption of modern irrigation systems, such as sprinkler and drip irrigation, can improve water use efficiency by up to 60% compared to conventional techniques (FAO, 2020). Therefore, introducing appropriate irrigation technologies tailored to local conditions is vital to ensure long-term sustainability.

rrigation efficiency refers to the ability of an irrigation system to deliver the required amount of water to crops with minimal losses through evaporation, seepage, or runoff. High efficiency ensures that water resources are utilized optimally, supporting both crop productivity and environmental conservation (FAO, 2020). In agricultural systems, where water demand continues to rise, efficient irrigation practices are critical to sustaining food production and addressing climate-related challenges.

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Studies have shown that traditional irrigation methods, such as surface irrigation and flooding, often result in significant water wastage. According to Ali et al. (2021), only about 30–40% of the applied water is effectively used by plants under such systems, while the rest is lost. In contrast, modern irrigation technologies such as drip and sprinkler systems can achieve efficiency levels above 70–90%, reducing water consumption while maintaining or even increasing crop yields.

Beyond water conservation, efficient irrigation also plays a vital role in agricultural sustainability. Sustainable irrigation contributes to:

1. Soil Health Preservation – By minimizing waterlogging and salinization risks caused by over-irrigation.
2. Energy Conservation – Efficient systems require less pumping power, reducing energy costs and carbon emissions.
3. Economic Sustainability – Farmers benefit from reduced input costs while achieving higher productivity.
4. Resilience to Climate Change – Improved irrigation management helps crops withstand irregular rainfall and drought conditions.

Recent advancements emphasize the integration of customized irrigation tools—including nozzle design improvements—to align water delivery with specific crop and soil requirements (Kumar & Singh, 2022). This approach not only enhances resource efficiency but also ensures long-term sustainability for smallholder farming systems.

Thus, irrigation efficiency is not merely a technical concern but a cornerstone of sustainable agriculture, linking water resource management with food security, environmental protection, and rural development.

Role of Nozzles in Irrigation Systems

Nozzles serve as the endpoint components of irrigation systems, directly controlling water flow, droplet size, and distribution uniformity. A well-designed nozzle minimizes water wastage and enhances soil moisture retention, which is crucial for crop growth (Kumar & Singh, 2022). Research highlights that nozzle geometry, material selection, and spray angle are decisive factors influencing system performance (Wang et al., 2019). However, in many developing countries, farmers continue to rely on low-quality, mass-produced nozzles that are prone to clogging and uneven distribution. This condition underscores the need for customized nozzle designs adapted to local agricultural demands.

Smallholder farmers often face limited access to advanced agricultural technologies due to high costs, lack of technical knowledge, and infrastructural constraints (Rahmawati et al., 2023). Innovations in simple, low-cost technologies have been proven effective in empowering local farmers to increase productivity. For example, community-based irrigation solutions in rural India demonstrated significant improvements in water savings and crop yields when custom-made irrigation tools were introduced (Patel & Desai, 2020). This evidence suggests that practical and accessible engineering solutions can bridge the gap between advanced technology and local resource availability.

Nozzles are a critical component of irrigation systems because they control the distribution, pressure, and flow rate of water applied to crops. The efficiency of an

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irrigation system often depends on nozzle design, as it directly influences how evenly and effectively water is delivered to the root zone (Smith & Jones, 2020). A well-designed nozzle ensures uniform coverage across the irrigated field. Non-uniform distribution can result in some plants receiving excess water while others remain under-irrigated, leading to reduced crop yield and inefficient use of water resources (Keller & Bliesner, 2019).

Nozzles determine the flow characteristics by regulating water discharge according to system pressure. For example:

a. High-pressure nozzles can generate fine sprays suitable for covering wide areas.
b. Low-pressure nozzles are more energy-efficient and reduce evaporation losses.

This flexibility allows farmers to match irrigation practices to specific crop needs and soil conditions. Traditional irrigation methods often waste water through runoff, deep percolation, and evaporation. Modern nozzle technologies—such as low-energy precision application (LEPA) nozzles—help minimize these losses by applying water closer to the soil surface (Howell, 2003).

Nozzle design can also reduce negative impacts such as soil erosion and crop damage. Large droplets from poorly designed nozzles can cause soil compaction and erosion, while very fine droplets may increase evaporation and drift. Therefore, nozzle selection must balance droplet size and application rate (Kincaid & Heermann, 2017).

By optimizing water flow, nozzles reduce the pumping energy required for irrigation. This efficiency lowers operational costs for farmers while contributing to sustainable resource use. Recent research emphasizes custom-designed nozzles tailored to specific agricultural needs, including crop type, field layout, and water availability. For instance, 3D-printed nozzles and adjustable spray patterns have been developed to maximize adaptability and performance (Patel et al., 2022).

Community Service and Higher Education in Technology Transfer

The Tri Dharma Perguruan Tinggi framework in Indonesia emphasizes education, research, and community service as the foundation of higher education institutions. Community service activities provide opportunities to translate academic research into real-world solutions that address societal challenges (Suryana & Hidayat, 2021). Previous projects in agricultural faculties across Indonesia have shown that collaboration between universities and farming communities fosters both technological innovation and social empowerment (Nasution et al., 2022). Thus, developing a custom irrigation nozzle within the Faculty of Agriculture UISU reflects not only a technical innovation but also a practical manifestation of community service in higher education. Despite global advancements in irrigation technologies, local adaptation and customization remain limited, particularly in Indonesian small-scale farming systems. Most studies focus on large-scale irrigation efficiency, whereas fewer address low-cost, context-specific nozzle innovations within academic and community settings. This research seeks to fill that gap by designing and implementing a custom nozzle as a community service project, integrating technical efficiency with social empowerment.

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METHOD

This community service project employed an applied research and participatory design approach to develop and implement a custom nozzle aimed at improving irrigation efficiency in the Agricultural Faculty of Universitas Islam Sumatera Utara (UISU). The method consisted of four main stages: needs assessment, nozzle design, fabrication, and implementation & evaluation. Observation and Interviews: The team conducted field observations and informal interviews with faculty staff and student farmers to identify common irrigation challenges, including water wastage, uneven distribution, and limited access to modern irrigation technology. Problem Identification: It was found that traditional watering methods (e.g., direct hose use) caused inefficient water use and inconsistent soil moisture levels, negatively affecting plant growth. This community service activity is carried out in several systematic stages to ensure that the results meet farmers' needs and can be effectively implemented in the field. The methods used in this activity include:

1. Needs Identification and Field Survey
   The initial step in this activity was to conduct a survey and identify farmers' needs regarding the irrigation systems currently used. The survey was conducted through interviews and direct observations at farm sites to understand the main challenges faced, including water efficiency, irrigation distribution, and the availability of affordable irrigation equipment.
2. Nozzle Design and Manufacturing
   Based on the survey results, a nozzle was designed to meet farmers' needs. The nozzle design was developed by considering technical aspects such as:
   a. A type of material that is durable and easy to obtain.
   b. Efficient and even water spray pattern.
   c. Ease of installation on various existing irrigation systems. After the design is drawn up, the next stage is to make a nozzle prototype using simple fabrication techniques so that it can be easily replicated by farmers.
3. Nozzle Testing and Evaluation
   The prototype nozzle was then field-tested, comparing its effectiveness to previous irrigation methods. This testing covered aspects such as:
   a. The resulting water distribution pattern.
   b. Efficient use of water.
   c. Ease of use by farmers

   The results of this trial are used to refine the design before it is implemented further. Once the nozzle is ready for use, training is provided on how to install, use, and maintain the equipment. This guidance is provided to ensure farmers can utilize the equipment optimally. This activity concludes with a monitoring and evaluation phase to assess the sustainability of the nozzle's implementation. User feedback serves as the basis for further development, ensuring the tool's continued utility and potential for widespread adoption in other agricultural communities. With this method, it is hoped that community service activities can produce useful and sustainable innovations in increasing the efficiency of plant watering and supporting more modern and water-efficient agricultural practices.

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RESULTS AND DISCUSSION

Manufacture and Characteristics of Watering Nozzles.

Based on the design and manufacturing results, the developed nozzle has a simple yet effective design that increases watering efficiency. This nozzle is made from durable and readily available materials, such as ABS plastic and corrosion-resistant metal.

The main characteristics of the manufactured nozzles include:

a. Even water spray pattern, so that all plants get sufficient water supply.
b. Adjustable water pressure, allowing use for a wide range of crops and soil conditions.
c. Ease of installation, because it can be integrated with existing hoses or irrigation systems.

Test results show that this nozzle is able to reduce water waste by up to 30% compared to conventional watering methods, as well as increase farmer labor efficiency. The implementation of the custom nozzle irrigation system produced significant improvements in water efficiency, distribution uniformity, and crop growth outcomes compared to the conventional irrigation method. The custom nozzle achieved an average flow rate of 1.8 liters/minute, optimized for vegetable and horticultural crops. The designed nozzle produced a spray angle of approximately 75°–90°, resulting in a uniform coverage area of 1.5–2 meters radius per nozzle.

The nozzle generated medium-sized droplets, minimizing water loss due to evaporation and reducing soil erosion compared to direct hose irrigation. Water usage decreased by 28% compared to traditional hose irrigation methods. This reduction was primarily due to improved distribution and reduced runoff.

Measurements showed a distribution uniformity index of 85%, significantly higher than the 60% achieved by traditional watering practices. Crops irrigated with the custom nozzle exhibited:

a. Faster germination rates (average 2 days earlier).
b. Healthier leaf color and structure, indicating better nutrient absorption.
c. An increase in average yield by 15% for vegetable crops over one planting cycle.

Faculty staff and students reported that the nozzle was simple to operate and required minimal technical expertise. The PVC and polyethylene construction allowed for easy cleaning and low-cost repairs. The system was perceived as a sustainable solution since it used low-cost, locally available materials and required no additional energy source other than gravity-fed or low-pressure pumps.

a. Occasional clogging occurred when the water source contained suspended particles, highlighting the need for a simple filtration system.
b. During peak irrigation, additional nozzles were required to ensure complete coverage for larger plots.

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Figure 2. Nozzle tool assembly

Nozzle Testing in the Field

Trials were conducted on agricultural land in partner areas, comparing manual watering methods with those using the developed nozzle. Observations and interviews with farmers revealed several key advantages:

1. Watering time is shorter than conventional methods.
2. Water needs are more controlled, so there is no excessive waterlogging that could potentially damage plants.
3. Plants grow more optimally because watering is more evenly distributed throughout the root area.

Farmers involved in the testing gave positive feedback and stated that this tool was very helpful in increasing their farming efficiency.

Figure 3. Nozzle tool test

Training and Mentoring for Participants

After the nozzle was successfully tested, the activity continued with training for farmer groups. The training covered installation, use, and maintenance of the nozzle to ensure its longevity and optimal function. Participants actively participated in discussions and hands-on practice, demonstrating high enthusiasm for this innovation. The training and mentoring sessions provided some input from farmers, such as the need to vary the nozzle

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hole size to suit different crop types. This input will form the basis for further development in the future.

Figure 4. Training for participants

The implementation of the custom nozzle irrigation system produced significant improvements in water efficiency, distribution uniformity, and crop growth outcomes compared to the conventional irrigation method.

Laboratory Testing Results

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CONCLUSION

The design and implementation of a custom irrigation nozzle at the Agricultural Faculty of UISU demonstrated that simple, low-cost technology can significantly improve irrigation ef-

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ficiency and crop productivity. Laboratory and field tests showed that the nozzle achieved uniform water distribution, reduced water consumption by nearly 30%, and enhanced crop yields by approximately 15%. Additionally, the system proved to be user-friendly, easy to maintain, and sustainable due to its reliance on affordable and locally available materials. From a community service perspective, this project not only provided a practical solution for optimizing water use in agriculture but also empowered students and local farmers with knowledge about efficient irrigation practices. The challenges observed, such as occasional clogging, can be addressed through the addition of simple filtration systems and proper maintenance. Overall, the custom nozzle irrigation system has the potential to serve as a replicable model for other agricultural communities facing similar water management issues. Its successful application at UISU highlights the importance of integrating simple technology innovations with community engagement to support sustainable agricultural practices and food security.

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