

Design and Fabrication of Customised Harvester for Removing Water Hyacinth

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Abstract - Water hyacinth (*Eichhornia crassipes*) is one of the most aggressive aquatic weeds, causing severe ecological imbalance and obstruction in water bodies. Conventional removal techniques such as manual extraction, chemical treatment, and large-scale mechanical harvesters are either labor-intensive, environmentally harmful, or economically unfeasible for rural applications. This paper presents the design, fabrication, and performance evaluation of a low-cost, floating water hyacinth harvester intended for small and shallow water bodies. The proposed system integrates a reciprocating cutting mechanism with a chain conveyor for continuous biomass collection, mounted on a lightweight pontoon structure to ensure stability and low draft operation. The harvester is powered by low-voltage DC motors, enabling energy-efficient operation with the potential for battery or renewable energy integration. An optional IoT-based control system using NodeMCU and the Blynk platform allows remote monitoring and control of key parameters. Experimental validation demonstrates effective weed removal with minimal power consumption and improved operational convenience. The developed prototype offers a cost-effective and sustainable alternative to conventional systems, making it suitable for decentralized deployment in rural and resource-constrained regions.

Key Words: Water hyacinth, Reciprocating cutter, Conveyor system, Pontoon stability, IoT, Node MCU, Remote monitoring

1.INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) has emerged as a highly invasive aquatic species that rapidly colonizes lakes, ponds, and irrigation channels, forming dense floating mats that obstruct sunlight penetration, reduce dissolved oxygen levels, and disrupt aquatic ecosystems while also hindering fishing, irrigation, and navigation activities. In rural and semi-urban regions, the problem is particularly severe due to limited access to efficient removal technologies. Existing control methods such as manual removal, chemical treatment, and large-scale mechanical harvesting each present significant drawbacks; manual methods are labor-intensive and slow, chemical approaches raise environmental and health concerns, and commercial harvesters are costly and unsuitable for shallow, narrow water bodies. These limitations highlight a clear research gap for a solution that is not only efficient but also affordable, locally manufacturable, and adaptable to constrained field conditions. To address this gap, the present work aims to design and develop a low-cost, floating water hyacinth harvester that integrates a reciprocating cutting mechanism, a chain conveyor for biomass collection, and a lightweight pontoon-based structure capable of operating in shallow waters with minimal power requirements. The primary objectives

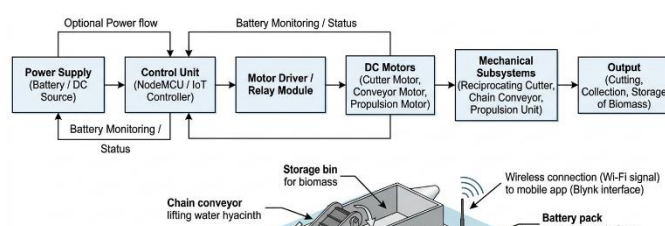
are to enhance removal efficiency, reduce operational effort, and ensure ease of fabrication and maintenance using locally available materials. The key contribution of this study lies in proposing a community-oriented, energy-efficient harvesting system with optional IoT-based monitoring, offering a practical and scalable alternative to conventional methods for sustainable aquatic weed management in resource-limited environments.

2. LITERATURE REVIEW

The rapid proliferation of water hyacinth (*Eichhornia crassipes*) and its high biomass productivity have been widely documented as major contributors to ecological imbalance and obstruction in aquatic systems, necessitating effective removal strategies [1], [4]. Mechanical harvesting has emerged as a preferred method due to its environmentally safe nature compared to chemical treatments, with existing designs typically employing cutting and conveyor mechanisms to remove and transport biomass [8]. However, most conventional systems are developed for large-scale applications and require significant power, making them unsuitable for shallow and narrow water bodies commonly found in rural areas. Advances in design engineering emphasize the importance of appropriate material selection and robust mechanical components to ensure durability and efficiency under such conditions [5]–[7]. More recently, the integration of automation and IoT technologies has been explored to enhance operational control and monitoring, using microcontrollers and wireless platforms to manage system performance; while these approaches improve functionality, they often increase system complexity and cost, limiting practical adoption in resource-constrained settings. Furthermore, existing removal methods present notable drawbacks: manual extraction is labor-intensive and inefficient, chemical control raises environmental and health concerns, and commercial harvesters are expensive and require skilled operation and favorable water conditions [2], [3]. Many current designs also fail to adequately address energy efficiency, cost optimization, ease of fabrication, and compliance with safety considerations in mechanical handling systems [10]. Overall, the literature reveals a clear gap in the development of a compact, affordable, and energy-efficient harvesting solution that can be locally fabricated and easily maintained, particularly for decentralized use in rural environments, thereby motivating the need for an integrated design approach as proposed in this work.

3. SYSTEM DESIGN AND METHODOLOGY

The proposed water hyacinth harvester is designed as a compact, floating mechanical system that integrates cutting, collection, and transport functions within a lightweight and energy-efficient architecture. The overall system consists of a pontoon-based floating platform that supports a reciprocating cutting mechanism at the front, a chain conveyor system for biomass lifting, a storage unit for temporary collection, and a low-power DC motor-driven transmission system



Parameter / System	Governing Equation	Description / Variables
Cutter Mechanism		
Slider-Crank Displacement	$x = r \cos\theta + \sqrt{l^2 - r^2 \sin^2\theta}$	Defines cutter position x based on crank radius r , connecting rod length l , and angle θ .
Velocity Equation	$v = \frac{dx}{dt}$	Instantaneous velocity of the reciprocating cutter blade.
Cutting Force	$F = \tau \times A$	Force required for cutting, where τ is shear strength of hyacinth stems and A is total cutting area.
Power Analysis		
Cutting Power	$P = F \times v$	Mechanical power consumed during the cutting action.
Motor Power	$P_{motor} = \frac{P}{\eta}$	Required electrical power input from the motor, considering mechanical efficiency η .
Conveyor System		
Conveyor Power	$P = \frac{W \times v}{\eta}$	Power to lift biomass, where W is load, v is speed, and η is conveyor efficiency.
Mass Flow Rate	$\dot{m} = \rho \times A \times v$	Rate of biomass collection, based on biomass density ρ , conveyor cross-sectional area A , and speed v .
Buoyancy & Stability		
Buoyant Force	$F_b = \rho \times g \times V$	Upward force from water, where ρ is water density, g is gravity, and V is displaced volume.
Floating Condition	$F_b \geq W_{total}$	Requirement for the harvester to float, ensuring total weight W_{total} is balanced by buoyancy.
Draft	$d = \frac{W}{\rho \times g \times A}$	Submerged depth d , related to total weight W and platform submerged area A .
Stability	$GM = \frac{I}{V} - BG$	Metacentric height GM , determining floating stability, using second moment of area I , displaced volume V , and vertical distance BG .
Energy & Efficiency		
Energy Consumption	$E = P \times t$	Total electrical energy used over time t of operation.
System Efficiency	$\eta = \frac{Biomass}{Energy}$	Overall efficiency ratio, dividing collected biomass mass by total consumed energy.

for actuation.

Fig -1: System block diagram

The working principle is based on continuous harvesting, where the front-mounted cutter severs the hyacinth stems near the water surface using a slider-crank-driven reciprocating blade, after which the cut biomass is immediately captured by a synchronized conveyor and transported onto the storage deck for later disposal. The use of twin pontoons ensures stability, low draft operation, and uniform weight distribution, enabling the system to function effectively in shallow and debris-filled water bodies. The design flow follows a structured engineering approach beginning with problem identification and field analysis, followed by concept generation and selection using evaluation matrices, and subsequent detailed mechanical design based on functional requirements such as cutting

efficiency, buoyancy, and energy consumption. Material selection is guided by strength-to-weight ratio, corrosion resistance, and cost considerations, while standard machine design principles are applied to ensure reliability and ease of fabrication. The methodology further includes prototype fabrication using locally available materials, integration of electrical and control systems, and iterative testing to refine performance parameters, resulting in a practical and scalable solution suitable for rural and resource-limited environments.

4. MECHANICAL DESIGN

The mechanical design of the proposed water hyacinth harvester focuses on achieving efficient cutting, smooth material handling, stable flotation, and reliable power transmission within a compact and low-cost framework. The primary cutting operation is performed by a reciprocating cutter mechanism driven by a slider-crank system, which converts rotary motion from a DC motor into linear motion to produce a shearing action capable of cutting both soft stems and fibrous roots of the hyacinth. This mechanism is selected for its higher cutting efficiency and lower torque requirement compared to rotary blades. The cut biomass is immediately transferred to a chain-based conveyor system positioned behind the cutter, which lifts and transports the vegetation onto an onboard storage unit while minimizing clogging and backflow through synchronized motion.

Table -1: Mechanical design considerations

The entire assembly is mounted on a floating structure supported by twin pontoons, designed using buoyancy principles to ensure adequate load-bearing capacity, low draft operation, and lateral stability even under varying biomass loads. The wide pontoon spacing enhances balance and prevents tilting during operation. Power from low-speed, high-torque DC motors is transmitted to both the cutter and conveyor through a simple chain and sprocket drive system, ensuring efficient energy transfer with minimal losses. The use of standard mechanical components and straightforward transmission arrangements improves reliability, ease of maintenance, and adaptability for local fabrication, making the overall mechanical system robust and suitable for deployment in shallow and debris-filled water environments.

5. ELECTRICAL AND CONTROL SYSTEM

5.1 MOTOR SELECTION AND POWER SUPPLY

The performance of the proposed water hyacinth harvester depends on the appropriate selection of motors and an efficient power supply system. The design emphasizes low power consumption, sufficient torque, and suitability for rural and portable applications.

Two DC geared motors are used in the system: one for driving the reciprocating cutter mechanism and the other for operating the conveyor system. Each motor is rated at 12 V and 50–60 W with a speed range of 40–70 RPM after gear reduction. These motors are selected to provide high torque at low speeds, which is essential for cutting fibrous plant roots and transporting wet biomass.

The torque produced by the motor is calculated using:

$$T = \frac{P}{\omega}$$

where P is the power and ω is the angular velocity. For a 60 W motor operating at 60 RPM:

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 60}{60} = 6.28 \text{ rad/s}$$

$$T = \frac{60}{6.28} \approx 9.55 \text{ Nm}$$

This torque is adequate for handling dense water hyacinth mats and ensuring smooth conveyor operation.

The system is powered by a 12 V rechargeable battery, chosen for its portability and compatibility with off-grid environments. A battery capacity of 7–12 Ah enables approximately 4 hours of continuous operation. The total power consumption of the system is:

$$P_{\text{total}} = 120 \text{ W}$$

The total energy consumed during operation is:

$$E = P \times t = 120 \times 4 = 480 \text{ Wh} = 0.48 \text{ kWh}$$

The system can also be integrated with solar charging units for sustainable operation in remote locations.

5.2 CONTROL CIRCUIT DESIGN

The control circuit is designed to be simple, reliable, and easy to maintain. It consists of a power source, microcontroller, relay module, switches, and protection devices.

A relay-based control mechanism is used to interface low-power control signals with high-power motor loads. A multi-channel relay module (typically 6-channel) is employed to independently control different

subsystems such as the cutter motor, conveyor motor, and propulsion system.

The NodeMCU microcontroller sends control signals through its GPIO pins to the relay module. Based on the input signal, the relay switches ON or OFF the corresponding motor. Manual override switches are also provided to ensure operation in case of controller failure.

The system incorporates essential safety features including an emergency stop switch, overcurrent protection using fuses or circuit breakers, and insulated wiring to prevent short circuits. Modular connections are used to simplify maintenance and component replacement.

Optional speed control can be implemented using Pulse Width Modulation (PWM), where the average voltage supplied to the motor is controlled by varying the duty cycle:

$$V_{avg} = D \times V_{supply}$$

where D is the duty cycle. This enables adaptive control of motor speed based on load conditions and improves energy efficiency.

5.3 IoT INTEGRATION USING NodeMCU AND BLYNK

To enhance system functionality, an IoT-based control and monitoring system is integrated using the NodeMCU (ESP8266) microcontroller and the Blynk platform.

The NodeMCU is a low-cost, Wi-Fi-enabled microcontroller that serves as the central control unit. It facilitates wireless communication between the hardware system and the user interface.

The Blynk platform provides a cloud-based interface accessible through a mobile application or web dashboard. It allows users to remotely control and monitor the harvester in real time.

The system architecture consists of the following communication flow:

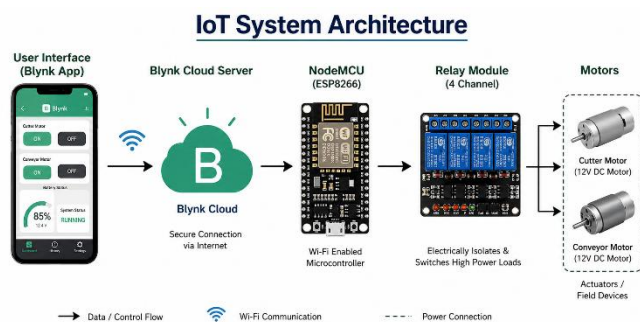


Fig -2: IoT Architecture

Through this setup, the operator can perform functions such as switching motors ON or OFF, monitoring

system status, and receiving alerts. Additional sensors can be integrated to provide real-time data such as battery voltage, motor current, and operational status.

The use of IoT improves operational safety by reducing the need for physical interaction with the machine and enables control in hard-to-reach or hazardous environments. It also provides a foundation for future automation and intelligent control systems.

Future enhancements may include integration of current sensors for load monitoring, GPS modules for tracking, and automated control based on weed density detection.

6. FABRICATION AND IMPLEMENTATION

Careful selection of materials is essential to ensure that the water hyacinth harvester is lightweight, corrosion-resistant, cost-effective, and durable. This chapter outlines the structured approach to material selection using engineering tools like Ashby charts and justifies the final choices for key components.

In the context of the water hyacinth harvester, the materials must meet the following performance goals:

- High strength-to-weight ratio (for floatability and transport)
- Good corrosion resistance (due to constant water contact)
- Moderate to low cost
- Ease of manufacturing (cutting, welding, shaping)
- Resistance to mechanical wear and impact

6.1 MATERIAL SELECTION

The selection of materials plays a crucial role in ensuring the durability, cost-effectiveness, and performance of the water hyacinth harvester. The materials were chosen based on key criteria such as strength-to-weight ratio, corrosion resistance, ease of fabrication, and availability.

Mild steel was selected for the main frame due to its high strength, low cost, and ease of welding and machining. Although it is prone to corrosion, protective coatings such as anti-rust paint are applied to enhance its lifespan. Stainless steel is used for shafts, fasteners, and bearings due to its superior corrosion resistance and durability in wet environments.

The cutting blades are fabricated from hardened steel to provide high wear resistance and maintain sharpness during continuous cutting operations. For the conveyor system, rubber or PVC-coated materials are used to ensure flexibility, water resistance, and effective grip on wet biomass.

The pontoons are constructed using PVC or high-density polyethylene (HDPE), which offer excellent

buoyancy, low weight, and resistance to water-induced degradation. Carbon steel and stainless steel components are used in the chain drive system to withstand repeated loading and mechanical stress.

Overall, the selected materials provide an optimal balance between mechanical performance, environmental resistance, and cost, making the system suitable for rural and semi-urban deployment.

Component	Material	Reason for Selection
Frame	Mild Steel(MS)	Cost-effective, strong, easy to weld and fabricate
Pontoon Shell	HDPE/PVC	Lightweight, corrosion-proof, good buoyancy proper
Cutting Blade(fixed)	Mild Steel(Hardened)	Strong edge retention economical, easy to sharpen
Cutting Blade(moving)	Hardened Steel	High wear resistance and impact strength
Conveyor Belt	Rubber/PVC Coated	Water-resistant, good grip, flexible under load
Bearings and Shafts	Stainless Steel(SS)	Corrosion-resistant, high fatigue life
Fasteners & Mounts	Stainless Steel	Prevents rusting in moist environments
Drive Chain & Sprockets	Carbon Steel/SS	Strong and durable under repeated loading

Table -2: Material selection

6.2 FABRICATION PROCESS

The fabrication of the harvester is carried out using conventional manufacturing processes that are accessible in standard workshops. The design emphasizes simplicity and modular construction to facilitate ease of manufacturing and maintenance.

The frame is fabricated by cutting and welding mild steel sections to form a rigid structure capable of supporting all components. Precision is maintained during fabrication to ensure proper alignment of mechanical systems.

The reciprocating cutter mechanism is manufactured using machining operations such as drilling, milling, and fitting. The slider-crank assembly is carefully aligned to ensure smooth motion and minimize vibration during operation.

The conveyor system is assembled using a chain and sprocket arrangement. Rollers and support structures are installed to guide the conveyor and maintain proper tension. The belt or chain is fitted with attachments to effectively lift and transport water hyacinth.

The pontoons are prepared by cutting PVC or HDPE pipes to the required length and sealing them to ensure watertight integrity. Mounting brackets are fabricated to securely attach the pontoons to the frame.

Standard components such as motors, bearings, shafts, and fasteners are integrated into the system using appropriate mounting techniques. Electrical wiring is carried out with proper insulation and routing to ensure safety and reliability.

6.3 ASSEMBLY OF THE PROTOTYPE

The assembly process is carried out in a systematic manner by integrating individual sub-systems into a complete functional unit.

Initially, the pontoon structure is mounted to the base frame to provide flotation and stability. The cutting unit is then installed at the front of the frame, ensuring proper alignment of the slider-crank mechanism and blade positioning.

The conveyor system is positioned directly behind the cutter to enable efficient transfer of cut biomass. Care is taken to synchronize the operation of the cutter and conveyor for continuous material flow.

The drive system, including motors and transmission components, is mounted and connected to the respective mechanisms using chain and sprocket arrangements. Proper tensioning and alignment are ensured to avoid mechanical losses and wear.

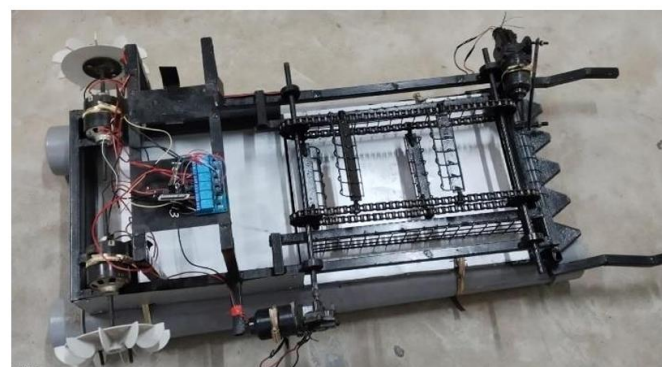


Fig -3: Full Assembly

Electrical components, including the battery, relay module, and control unit, are installed and connected according to the circuit design. Safety features such as emergency stop switches and protective enclosures are incorporated.

After complete assembly, the system undergoes initial testing to verify mechanical movement, electrical functionality, and buoyancy performance. Adjustments are made as required to ensure smooth operation and reliability.

The final prototype is thus a compact, modular, and efficient system capable of operating in shallow water bodies for effective removal of water hyacinth.

7. EXPERIMENTAL SETUP

7.1 TEST CONDITIONS

The experimental evaluation of the proposed water hyacinth harvester was conducted under controlled and real-time operating conditions to assess its performance and reliability.

The prototype was tested in a shallow water body containing naturally grown water hyacinth. The average water depth during testing ranged between 0.5 m and 1 m, representing typical rural pond conditions. The surface coverage of water hyacinth was moderately dense, forming interlinked mats of vegetation.

The harvester was powered using a fully charged 12 V battery, and all systems, including the cutter and conveyor, were operated simultaneously. Environmental conditions such as temperature, water flow, and wind were observed to be within normal limits, ensuring minimal external disturbance during testing.

The machine was operated by a single user to evaluate ease of handling and maneuverability. Multiple test runs were conducted to ensure consistency and repeatability of results.

7.2 PERFORMANCE PARAMETERS

The performance of the harvester was evaluated based on key measurable parameters that reflect its efficiency, energy consumption, and operational effectiveness.

The primary performance parameters include:

- **Biomass Removal Rate (kg/h):**

The quantity of water hyacinth removed per unit time, indicating the effectiveness of the cutting and conveying system.

- **Cutting Efficiency (%):**

The ability of the cutter to successfully sever plant stems and roots without clogging or incomplete cuts.

- **Power Consumption (W):**

The total electrical power consumed by the cutter and conveyor motors during operation.

- **Energy Efficiency (kg/kWh):**

The ratio of biomass removed to energy consumed, representing the system's energy utilization.

- **Operational Stability:**

The ability of the harvester to maintain balance and steady operation during loading and movement.

- **Maneuverability:**

The ease with which the operator can control and navigate the machine in confined and vegetation-dense areas.

- **System Reliability:**

The consistency of performance without mechanical failure, overheating, or excessive vibration.

7.3 TESTING PROCEDURE

The testing procedure was carried out in a systematic manner to ensure accurate evaluation of the harvester's performance.

1. The prototype was placed in the water body, and initial checks were conducted to verify buoyancy and stability.
2. The cutter mechanism was operated independently to observe the smoothness of reciprocating motion and effectiveness of cutting action.
3. The conveyor system was then activated to ensure proper rotation, alignment, and material handling capability.
4. Both cutter and conveyor systems were operated simultaneously, and the harvester was moved forward through the water hyacinth mat.
5. The time taken to clear a specific area was recorded, and the collected biomass was measured to determine the removal rate.
6. Power consumption was monitored during operation to evaluate energy usage.
7. Observations were made regarding system stability, ease of control, and any mechanical or electrical issues.
8. The system was inspected after each test run to identify wear, misalignment, or overheating of components.

8. RESULTS AND DISCUSSION

8.1 BIOMASS REMOVAL EFFICIENCY

The harvester achieved an average biomass removal rate of 45–55 kg/h under moderate density conditions. The cutting efficiency was approximately 85–90%, with effective removal of stems and roots. Minor inefficiencies were observed in highly dense regions.

8.2 POWER CONSUMPTION ANALYSIS

The total power consumption of the system was around 110–130 W. For 4 hours of operation, energy usage was approximately 0.48 kWh. The system demonstrated high energy efficiency of about 100 kg/kWh, making it suitable for battery-powered operation.

8.3 SYSTEM PERFORMANCE EVALUATION

The system showed stable operation with good buoyancy and maneuverability. It was operable by a single user and exhibited reliable performance with minimal vibration. Minor maintenance issues such as blade wear and conveyor alignment were observed.

8.4 COMPARISON WITH EXISTING METHODS

Compared to manual and chemical methods, the proposed system offers higher efficiency. In comparison to commercial harvesters (₹3–8 lakhs), it is significantly cost-effective (₹11,000–13,000) and consumes much lower power (~120 W), making it suitable for rural applications.

9. ENVIRONMENTAL AND SOCIAL IMPACT

9.1 ECOLOGICAL BENEFITS

The removal of water hyacinth using the proposed harvester provides significant ecological benefits to affected water bodies. Water hyacinth is known to form dense mats on the surface, which block sunlight penetration and reduce dissolved oxygen levels, thereby harming aquatic life. By efficiently clearing this vegetation, the system helps restore natural light availability and oxygen balance, improving overall water quality.

The removal process also enhances water flow in irrigation channels and prevents stagnation, which is a major cause of mosquito breeding and water-borne diseases. Unlike chemical treatment methods, the proposed mechanical approach does not introduce harmful substances into the ecosystem, making it an environmentally safe solution.

Additionally, the harvested biomass can be repurposed for composting, biogas production, or other value-added applications, contributing to sustainable waste management. Overall, the system supports ecological restoration while minimizing environmental impact.

9.2 RURAL APPLICATION ADVANTAGES

The proposed harvester is specifically designed to address the needs of rural and semi-urban communities. Its low cost, simple construction, and ease of operation make it accessible to local users such as farmers, fishermen, and panchayat bodies.

The system can be fabricated and maintained using locally available materials and basic workshop facilities, reducing dependency on expensive commercial equipment. Its low power requirement allows operation using batteries, and it can be further integrated with solar energy systems for off-grid use.

The use of this harvester can generate local employment opportunities in fabrication, operation, and maintenance. It also supports agricultural and fishing activities by keeping water bodies clean and functional.

Overall, the proposed system empowers rural communities with an affordable and practical solution for water body management, contributing to improved livelihoods and sustainable development.

10. CONCLUSION

The design and development of the customized water hyacinth harvester successfully address the need for an affordable, efficient, and eco-friendly solution for managing invasive aquatic vegetation. The system integrates a reciprocating cutter mechanism, chain conveyor, and pontoon-based floating structure, enabling effective removal of water hyacinth in shallow and constrained water bodies.

Experimental results demonstrate that the harvester achieves satisfactory biomass removal efficiency with low power consumption, making it suitable for battery-operated and potentially solar-powered applications. The mechanical design ensures stable operation, ease of control, and minimal maintenance requirements, allowing it to be operated by a single user in real field conditions.

Compared to conventional methods such as manual removal, chemical treatment, and high-cost commercial machines, the proposed system offers a balanced solution in terms of cost, performance, and environmental impact. Its modular construction and use of locally available materials further enhance its practicality for rural deployment.

Overall, the developed harvester provides a sustainable and scalable approach to aquatic weed management, supporting ecological restoration, improving water resource utilization, and enabling community-level implementation. With further enhancements in automation and energy integration, the system has strong potential for wider adoption and future development.

11. FUTURE WORK

- **Automation Enhancements:** Integration of sensors and microcontrollers (e.g., Arduino) for automatic start/stop based on weed detection and motor load conditions.
- **Solar Integration:** Implementation of solar panels for battery charging to enable fully renewable and off-grid operation.
- **Improved Storage System:** Development of larger or detachable storage units for faster unloading and increased biomass capacity.
- **Navigation Control:** Addition of rudder or joystick-based remote control for better steering and maneuverability.
- **Multi-Use Capability:** Modification of the system to handle other floating waste such as plastics and debris.

- **Data Monitoring:** Integration of GPS, water quality sensors, and IoT systems for real-time monitoring and performance tracking.

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