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DEVELOPMENT OF A SOLAR ASSISTED SMART AGRICULTURAL MACHINE

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ABSTRACT

Agriculture plays a significant role in food production and economic growth. However, farming operations such as seed sowing, grass cutting, and water spraying are often performed manually, requiring considerable labor, time, and cost. To overcome these challenges, this project is proposed to develop of a solar-based remote-controlled multipurpose agricultural machine. The proposed machine integrates three essential agricultural operations, seed sowing, grass cutting, and water spraying into a single compact system. The seed sowing mechanism is designed to release seeds at regular intervals, helping achieve more uniform planting while reducing seed wastage. The grass-cutting mechanism removes weeds between crop rows, reducing manual labor, and the water spraying system provides controlled irrigation for small-scale farming applications. Combining these functions into a single machine reduces equipment costs, saves time, improves operational efficiency, and minimizes dependence on fossil fuels by using renewable solar energy. It is powered by a solar panel, which charges a rechargeable battery through a solar charge controller. The stored electrical energy is used to operate the drive motors, grass-cutting motor, water pump, and electronic control system. An microcontroller enables wireless remote control, allowing the operator to move the machine and independently control each operator to move the machine while independently controlling the grass cutter and water spraying system from a safe distance.

INTRODUCTION

Agriculture depends on timely execution of field operations, including sowing, irrigation, weed management, and crop maintenance. In small and fragmented fields, these activities are often performed manually or with separate equipment. Such arrangements may increase labour requirements, operating time, and the number of tools that must be maintained. Mechanised systems can reduce repetitive effort, while compact mobile platforms may be more appropriate than large machinery for gardens, nurseries, and small plots [1-3].

Agricultural robotics research covers task-specific platforms for monitoring, spraying, weeding, and harvesting. Recent reviews identify energy endurance, terrain variability, navigation reliability, and safe actuation as important deployment considerations [4]. Field robots have also been developed to perform multiple crop-management tasks, demonstrating the value of integrating mechanisms on a mobile platform [5,6].

The present work focuses on a relatively simple, remotely operated prototype rather than a fully autonomous field robot. Its intended contribution is the integration of three basic operations—seed sowing, grass cutting, and water spraying along with solar-assisted battery charging. The system is designed for small-scale use and educational demonstration. Its suitability for field deployment must be established through repeatable tests under defined operating conditions.

MATERIALS AND METHODS

The development process included system planning, component selection, chassis fabrication, mechanical assembly installation, electrical integration, controller programming and subsystem inspection. The hardware arrangement was described in the project report and illustrated by supplied photographs. Where a rating could not be read or was not on record, it is deliberately not assumed.

System Architecture

There are five subsystems involved in the machine, and these include: (i) Mechanical Chassis & Mobility, (ii) Solar-powered Energy Source, (iii) Electronic Control and Wireless Communication, (iv) Seed Planting System, and (v) Grass Cutting & Water Spraying Systems. The chassis carries all components including the panel, batteries, motors, water tank, electronic control unit, and task performers. There are four wheel motors for mobility.

Operating Sequence

Sunlight is converted into DC electrical energy by the photovoltaic panel. The output is connected to a solar charge controller and then to the rechargeable battery, subject to correct voltage and polarity matching. During operation, the battery supplies the control electronics and motor circuits. The operator sends a wireless command; the ESP32 processes the command and generates control signals for the motor drivers or switching devices. The selected mechanism is then activated while the operator supervises the machine.

Mechanical Structure and Mobility

A fabricated frame forms the load-bearing structure of the prototype. It supports the photovoltaic panel, battery, control unit, water tank, drive motors, and agricultural mechanisms. Four DC motors are associated with the four wheels. Differential control of the left- and right-side motors can provide forward and reverse movement and turning, depending on the implemented wiring and control logic. The chassis should be checked for adequate stiffness, secure motor mounting, balanced component placement, and sufficient ground clearance.

Solar-Assisted Electrical System

The photovoltaic panel is connected to a solar charge controller, which regulates charging of the rechargeable battery. The battery acts as the stored-energy source for the electrical loads. A complete energy assessment requires the panel rated power and electrical characteristics, battery nominal voltage and ampere-hour capacity, controller rating, charging current, and load current under operating conditions. These numerical specifications were not fully available in the supplied report and should be transcribed from the component labels or datasheets.

Electronic Control

An ESP32 development board is identified in the project documentation as the main control unit. It receives wireless operating commands and provides logic-level signals to suitable driver or switching circuits. The driver stage is required because microcontroller GPIO pins cannot directly supply the current demanded by drive motors, the cutting motor, or the water pump. The project report identifies an L298N-type dual H-bridge module in the hardware photographs; its suitability must be checked against the actual motor current and thermal requirements. The report also indicates that the pump label appears to show 12 V DC and 4.5

A, corresponding to approximately 54 W at those stated values. This rating should be verified from the pump label before final circuit selection.

Seed-Sowing Mechanism

The seed-sowing assembly consists of a hopper and a dispensing arrangement intended to release seeds while the machine moves. Seed delivery is affected by the hopper geometry, outlet size, seed shape and size, vibration, and travel speed. For repeatable sowing, the dispensing mechanism should be tested using a known seed quantity and a measured travel distance. Seed spacing and missed or multiple drops should be recorded rather than inferred from visual inspection alone.

Grass-Cutting Mechanism

The grass-cutting assembly uses an electric motor to rotate a cutting blade. The motor and blade are mounted to the chassis, with the cutting assembly positioned to contact the vegetation. The blade must be securely fastened, balanced, and enclosed by a suitable guard. Motor voltage, current, rotational speed, blade diameter, cutting width, and cutting height should be documented from measurement or manufacturer data.

Water-Spraying Mechanism

The water-spraying assembly includes a storage tank, DC pump, connecting pipe, and outlet/nozzle. When activated, the pump draws water from the tank and delivers it to the spray outlet. The pump must be powered through a switching device or driver rated for its starting and running current. Electrical connectors should be protected from water, and the pipework should be checked for leakage.

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Prototype Fabrication and Integration

The prototype was assembled on a fabricated chassis. The drive motors and wheels were mounted to provide mobility. The upper structure carries the photovoltaic panel, while the battery and electrical components are positioned on the lower platform. The water container and pump assembly are mounted on the frame and connected to the spray outlet through tubing. The seed-dispensing and grass-cutting mechanisms are intended to operate as separate task units.

The fabrication and integration sequence can be summarised as follows:

- Fabricate the chassis and provide mounting points for the wheel motors and major components.
- Install the four wheel motors and wheels, and verify free rotation and mechanical alignment.
- Mount the seed hopper and dispensing arrangement, ensuring that seed flow is not obstructed.
- Install the grass-cutting motor and blade assembly with appropriate guarding and secure fasteners.
- Mount the water tank, pump, pipework, and nozzle; inspect all joints for leakage.

- Install the photovoltaic panel, charge controller, rechargeable battery, ESP32 board, and driver circuits.
- Complete wiring with correctly rated conductors, connectors, fuse protection, and insulated terminals.
- Program the controller and test each actuator separately before attempting integrated operation.



Fig. 1. Side view of the assembled solar-assisted agricultural machine prototype.

Electrical and Mechanical Safety

The cutting blade presents a mechanical hazard and must be guarded during operation. Testing should be performed in a controlled area with people kept clear of the blade path. Power must be isolated before servicing or adjusting the cutting assembly. The battery circuit should include suitable overcurrent protection, secure terminals, and wiring sized for the expected current. The pump circuit should use a driver or relay/MOSFET arrangement rated for the verified pump current; a small motor-driver module should not be assumed adequate without checking its continuous and peak ratings. Water paths and electrical terminals should be physically separated and protected.

Design Relations for Subsequent Validation

The following basic relations can be used when actual component ratings and measurements are available:

Electrical input power: $P = V I$

Battery nominal energy: $E = V_b C_b$ *(Wh, when* C_b *is in Ah)*

Wheel torque requirement: $T = F r$

Wheel rotational speed: $n = 60 v / (2\pi r)$

where V is voltage, I is current, V_b is battery voltage, C_b is battery capacity, F is the required tractive force, r is wheel radius, v is linear speed, and n is wheel speed in revolutions per minute. These relations are design tools; numerical outputs should only be reported after inserting verified prototype values.

DISCUSSION

The photographs show a compact wheeled machine with a raised support frame, a photovoltaic panel, a solar charge controller, a battery, and mounted mechanical/electrical components. This supports the description of a physically assembled prototype rather than a purely conceptual design. The photographs alone, however, cannot establish the machine's operating speed, seed distribution quality, grass-cutting capacity, spray uniformity, or solar charging contribution.

The integration of multiple actuators creates a shared power-management challenge. Simultaneous operation of the drive motors, cutting motor, and pump can increase the electrical load and reduce the time for which the battery can supply the system. The final driver selection must be based on measured or datasheet current, including motor starting current. The apparent pump rating of 12 V and 4.5 A, if confirmed, represents an electrical input of about 54 W and should be treated as a substantial load for a small prototype.

Limitations

- The prototype is intended for small-scale applications; its suitability for large fields has not been established.
- Solar charging depends on irradiance, panel orientation, shading, and the panel/controller/battery ratings.
- Battery runtime under individual and combined loads has not been quantified.
- Seed release consistency may vary with seed geometry, hopper design, and travel speed.
- Cutting performance depends on vegetation type, blade geometry, speed, and available motor power.
- Spray discharge and coverage depend on pump characteristics, nozzle selection, pipe losses, and battery condition.
- Performance on uneven or wet soil has not been established through documented field trials.

Further Experimental Validation

Before submission as an experimental research article, the authors should complete at least three repeat trials for each subsystem, report the mean and standard deviation, state the test conditions, and include photographs of the test setup. If these measurements cannot be obtained, the manuscript should be submitted only to a venue that accepts design-and-development or prototype-description papers, and its claims should remain limited to the demonstrated construction and intended functions.

CONCLUSION

A compact solar-assisted smart agricultural machine integrating seed sowing, grass cutting, and water spraying has been described. The prototype combines a wheeled chassis, four DC drive motors, an ESP32-based wireless control arrangement, a photovoltaic panel and charge controller, a rechargeable battery, and separate agricultural task mechanisms. The design aims to bring three basic operations onto one remotely controlled platform for small-scale agricultural applications.

The supplied report and photographs support the description of the prototype configuration and its principal subsystems. However, quantitative performance data were not available for seed spacing, cutting rate, water discharge, solar charging, or battery endurance. Consequently, the present paper does not make numerical claims about accuracy, efficiency, energy savings, or productivity. Controlled testing and verified component specifications are required to establish these performance characteristics.

Future Scope

Future development should prioritise a verified power budget, battery voltage/current monitoring, low-voltage cut-off, fuses, and appropriately rated motor drivers. The seed metering unit can be improved through an adjustable dispensing mechanism to accommodate different seed sizes and target spacing. The cutting assembly can be enhanced through blade guarding, vibration reduction, and cutting-height adjustment. A flow-control arrangement and soil-moisture sensing could improve water application. Obstacle detection, row-following, GPS-assisted guidance, and autonomous navigation may be considered after the basic remote-controlled platform has been validated. Field trials on different soil and vegetation conditions are necessary before assessing scalability.

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