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Design and Fabrication of the Automatic Multipurpose Agriculture Robot (AMAR)

Daim Badar[1], Corresponding Author[1,*], Dr. Badar ul Islam[2]

[1] Department of Mechanical and Manufacturing Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim yar khan, Pakistan
[2] Department of Electrical Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim yar khan, Pakistan

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ABSTRACT

Agriculture is among the many industries that have greatly profited from the quick development of robots and automation. AMAR will automate diverse agricultural tasks, minimize physical labour, promote sustainable agriculture, increase profitability for farmers, precision seed sowing, and optimize resource use. The automatic multipurpose agricultural seed sowing robot, a state-of-the-art autonomous machine is designed to prepare the garden bed afterward sowing the seeds and then used for watering them at the same time with efficient solar power and all this could be done automatically with the use of a mobile app. It combines computer vision and precision mechanics to ensure efficient and precise seed sowing across various crops and terrains. The robot analyses optimal seed placement, ensuring even distribution. Energy-efficient and eco-friendly, it reduces labour costs, increases productivity, and enhances crop yields, fostering sustainable agricultural practices and improving profitability for farmers. This technology is designed to improve the overall farming industry in terms of profitability and labour-saving. Photovoltaic technology is the ultimate solution for cost-saving benefits and is incorporated into the robot.

1. Introduction

The agriculture sector holds significant importance for Pakistan's economy and the livelihoods of its people. It is one of the country's largest industries, contributing substantially to its GDP and employing a substantial portion of the workforce. As of my last update in September 2021, here are some key points about the agriculture sector in Pakistan:

1.1 Contribution to GDP

The agriculture sector contributes around 20% of Pakistan's GDP, making it a crucial driver of economic growth. The major sector of our economy is agriculture. The majority of people are reliant on this industry, either directly or indirectly. It makes up half of the

[*] *Corresponding author.*
E-mail address: daimbadar988@gmail.com

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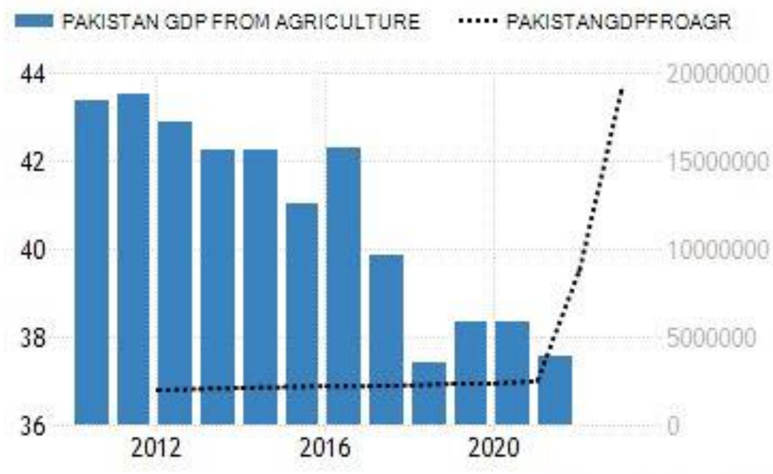
employed labor force, accounts for around 24 percent of the GDP, and is the main source of foreign currency profits According to the World Bank's collection of development indicators, which was produced from officially recognized sources, employment in agriculture (% of total employment) (modeled ILO estimate) in Pakistan was recorded as 37.54% in 2021. Actual statistics, historical data, forecasts, and estimates for Pakistan's employment in agriculture (as a percentage of all employment) were obtained from the World Bank in July 2023. Persons of working age who participated in any activity to produce products or offer services for pay or profit are considered to be employed, regardless of whether they were working during the reference period or not owing to a brief absence from a job or a working-time arrangement. The agricultural sector includes operations classified as division 1 (ISIC 2), categories A-B (ISIC 3), or category A (ISIC 4) in agriculture, hunting, forestry, and fishing.



Agriculture sector contributes

1.2. Challenges:

The sector faces various challenges, including water scarcity, outdated farming practices, limited access to modern technology, and post-harvest losses. The available land for cultivation is restricted in size. Pakistan has a total land area of around 79.6 million hectares, with 24.1 million hectares dedicated to agricultural activities. Approximately 8.28 million hectares of land are now unused and not being used. The presence of extensive fragmentation in land ownership hinders the effective use of new technological advancements within the agricultural industry.

International conflicts refer to disputes or disagreements that arise between nations or states on a global scale. These conflicts may include a wide range of issues, such as territorial disputes, ideological ones. The economy of Pakistan is significantly impacted by major economic forces. Pakistan is a notable importer of wheat, pulses, and oilseeds from Russia and Ukraine. In the previous year, the combined imports from Russia and Ukraine accounted for 77.3 percent of the total wheat imports, 19.3 percent of the total pulses imports, and 10.4 percent of the total oilseed imports into the nation. The problem at hand is anticipated to increase in global costs for fertilizers and energy. In a similar vein, the United States offers India more affordable rates for superior quality seeds and chemicals in comparison to Pakistan.

The growth rate of associated products is somewhat sluggish. associated products include non-agricultural goods and services that indirectly contribute to enhancing the farmer's quality of life. Pakistan exhibits inadequacy in the production of fruits, milk, poultry, fishery, livestock, and forests. Consequently, the substandard quality of our food not only hampers our overall well-being, but also impedes the growth and advancement of several businesses, like furniture, textiles, and dairy. One of the primary concerns in the field of agriculture is the insufficient yield per hectare seen across many key crops. Based on the data provided by PES 2021-22, it can be seen that the proportion of the labor force involved in this particular sector in Pakistan amounts to 37.4%, but in industrialized nations, this figure is notably lower, standing at less than 3%. However, it is worth noting that many other nations throughout the globe have achieved better yields per acre as a result of using advanced technologies and skilled labor. The use of mechanization in agriculture is undoubtedly on the rise in Pakistan. However, it is worth noting that in many regions, traditional tools and equipment continue to be employed. Traditional manufacturing methods are unable to meet worldwide requirements in terms of increasing productivity. Inadequate training and insufficient technological resources contribute to pre- and post-harvest losses. The country of Pakistan faces a scarcity of inputs and research, particularly about the availability and consistency of contemporary inputs such as high-yielding variety (HYV) seeds, chemicals, fertilizers, pesticides, and mechanized equipment. These inputs are not only expensive but also insufficient and inconsistent in their delivery. Fertilizer is a primary and costly input. The use of an optimal amount of fertilizer has the potential to enhance the agricultural production of diverse crops by a range of 30% to 50% throughout different regions of the nation. Continuous progress in agricultural research is vital to enhance the potential of agricultural output.

The manual labor required by conventional seed-sowing techniques in agriculture frequently results in inefficiencies, inconsistent seed placement, and higher operating costs for farmers. Additionally, the optimization of seeding operations is hampered by the absence of real-time monitoring and control. The project seeks to create a Multipurpose Seed Sowing Agriculture Robot (MSSAR) that can be autonomously operated via a mobile application to address these issues

2 Literature Review

In this study, Muhammad Usman focuses on analyzing the contribution of the agriculture sector to the GDP growth rate of Pakistan. Usman's research likely utilizes various statistical methods and economic indicators to assess the extent to which the agriculture sector influences the GDP growth rate. The study may explore factors such as agricultural productivity, employment generated by the sector, and the export of agricultural products. Given the limited information provided in the summary, the specific findings and conclusions of the study are not detailed here [1]. However, the research likely sheds light on the critical role of the agriculture sector in Pakistan's economic growth and development.

In this paper authored by Md. Tofazzal Hossain Rahman and published in the International Journal of Business and Management Invention in 2017, the focus is on examining the role of agriculture in the economy of Bangladesh. The research likely employs a combination of qualitative and quantitative methods to assess the significance of agriculture in the overall economy of Bangladesh. It might include the analysis of agricultural productivity, contribution to GDP, employment generation, and export performance of agricultural products. Rahman's study delves into the challenges and obstacles that hinder the full potential of the agricultural sector in Bangladesh [2]. These challenges may encompass issues related to technological advancements, infrastructure development, access to finance, market integration, climate change, and policy constraints.

Mohammad Valipour and published in the Archives of Agronomy and Soil Science in 2014, the focus is on studying the interrelated issues of drainage, water logging, and salinity in agricultural lands. The study likely investigates the adverse effects of improper drainage practices, water logging, and salinity on agricultural productivity and soil health. It may delve into the mechanisms through which water logging and salinity occur in agricultural fields and explore their impacts on crop growth, soil structure, and nutrient availability. Valipour's research is expected to propose and assess various drainage techniques and practices aimed at mitigating water logging and salinity problems. These techniques could include subsurface drainage systems, surface drainage methods, and strategies to manage excess water in the root zone of crops **Error! Reference source not found.**.

Kritika Jha, Ankit Doshi, Pratik Patel, and Maitri Shah, provide a comprehensive overview of the application of artificial intelligence (AI) in the agricultural sector. The work is likely to discuss different AI techniques used in agriculture, including machine learning, computer vision, natural language processing, and robotics. It may highlight specific case studies and practical applications where AI has been successfully employed to optimize farming practices, reduce resource wastage, and enhance overall agricultural productivity. Furthermore, the article may explore the challenges and limitations of implementing AI in agriculture, such as the need for high-quality data, farmer acceptance, and the cost of adopting AI technologies. It might also suggest future research directions and potential areas where AI can further contribute to sustainable and efficient agricultural practices **Error! Reference source not found.**.

In this work authored by Subhashish Shome and Dipankar Mal, the focus is on exploring the potential of reviving traditional Indian indigenous agricultural practices that incorporate cow-based products. They might also elaborate on how these indigenous practices have been an integral part of rural farming for generations. The article is likely to shed light on the environmental and economic benefits of adopting such practices. Additionally, the work discusses the challenges and obstacles in the widespread adoption of these traditional practices in the context of modern agriculture [5]. The authors explore ways to overcome these challenges and promote the integration of cow-based products into contemporary farming systems by advocating for the revival of indigenous agricultural practices, the authors aim to contribute to the promotion of sustainable and eco-friendly farming methods in India and potentially in other regions facing similar agricultural challenges.

In this research article authored by Arun Vadivelu and B. R. Kiran, and published in the International Journal of Agricultural and Food Science in 2013, the focus is on examining the challenges and opportunities in the agricultural marketing sector in India. The article likely presents a comprehensive overview of the problems faced by agricultural marketing in India. It may delve into issues related to market infrastructure, post-harvest losses, transportation bottlenecks, storage facilities, and price fluctuations. The authors present an analysis of the existing agricultural marketing policies and their effectiveness in addressing the challenges faced by farmers and traders [6]. They may also propose policy recommendations to create a more efficient and inclusive marketing system for agricultural products. By providing an overview of the problems and prospects of agricultural marketing in India, the article serves as a valuable resource for policymakers, researchers, and stakeholders interested in improving the agricultural marketing infrastructure and promoting sustainable growth in the agricultural sector.

In this research study conducted by You Hong Gan and Elizabeth H. Stobbe and published in the Canadian Journal of Plant Science in 1995, the focus is on investigating the impact of variations in seed size and planting depth on the emergence, infertile plants, and grain yield of spring wheat. The study likely involves experimental research in which different seed sizes of spring wheat are used and planted at varying depths. The authors may explore how these factors influence the germination and emergence rates of the wheat plants, as well as the occurrence of infertile or non-productive plants in the field. The authors examine whether there are any significant differences in yield based on these variations and provide insights into how farmers can optimize seed size and planting depth to achieve better crop performance and higher yields [7]. The study's findings are expected to shed light on the importance of seed size and planting depth as critical factors that can influence crop establishment and productivity in spring wheat cultivation.

In this research paper presented at the 2019 3rd International Conference on Electronics, Communication, and Aerospace Technology (ICECA), authors B. Ranjitha, M. N. Nikhitha, K. Aruna, and B. V. Murthy introduce a solar-powered autonomous multipurpose agricultural robot that can be controlled using Bluetooth technology and an Android application. The robot is equipped with a solar power system, allowing it to operate autonomously without reliance on external power sources. The integration of Bluetooth technology enables users to control the robot's movements and functions remotely through a dedicated Android application. The authors are likely to explain the various capabilities of the agricultural robot **Error! Reference source not found.**. The autonomous nature of the robot makes it a potentially valuable tool for enhancing agricultural practices, reducing labor requirements, and improving overall farm efficiency.

This work authored by Mahantesh Poojari, Hanumanthappa Hanumanthappa, Chethan D Prasad, Harish M Jathanna, A R Ksheerasagar, Prashanth Shetty, B K Shanmugam, and Harish Vasudev, and published in the International Journal on Interactive Design and Manufacturing (IJIDeM) in 2023, focuses on computational modeling for the manufacturing of a solar-powered multifunctional agricultural robot. The study likely presents an in-depth analysis of the design and manufacturing process of the solar-powered agricultural robot **Error! Reference source not found.**. The authors may discuss how computational modeling techniques, such as computer-aided design (CAD) and simulation tools, have been utilized to optimize the robot's design, structural integrity, and functionality.

In this research paper authored by Praveen Kumar and Gnanamurugan Ashok, published in Materials Today: Proceedings in 2021, the focus is on the design and fabrication of a smart seed sowing robot. The study likely presents the development of an autonomous robot designed specifically for sowing seeds in agricultural fields. The authors may describe the robot's mechanical and electronic components, including sensors and actuators, that enable it to perform seed sowing tasks efficiently [10].

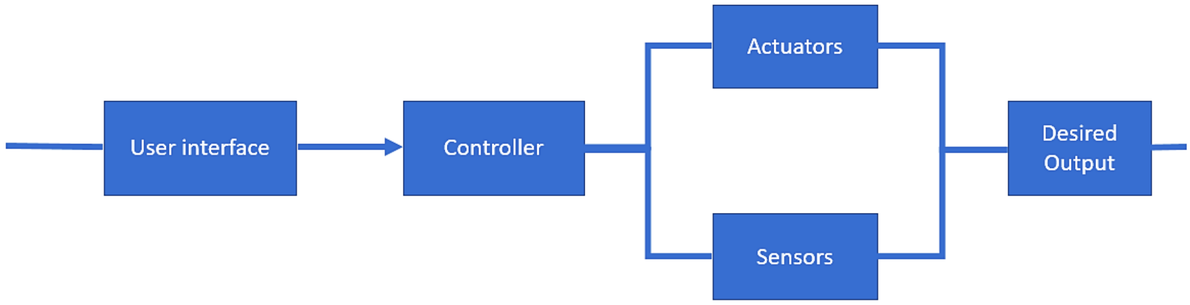
3. Methodology

This robot is designed because Agriculture is the backbone of Pakistan There is a demand in agriculture for technology that is simpler for farmers to use, understand, and put into practice. The agricultural business relies heavily on equipment that can be implemented quickly, cheaply, and with little human labor. **Error! Reference source not found.**

A seed sowing robot is a tool that assists farmers in saving time and money by helping to spread seeds at the desired location. One of the primary agricultural procedures is seed planting. It is time-consuming and requires a lot of human work. The purpose of this project is to develop and create a smart seed-planting robot for the aforementioned duty. One robotic arm on this clever seed-planting machine spreads the seeds from the seed container. **Error! Reference source not found.**

The smartphone application is used to operate the robot arm and move it into the required places. When the switching button is pressed ON after all the locations have been established, the arm automatically plants the seed.

By using a command-and-control mechanism A control system for a seed sowing machine will normally consist of several different components, including sensors, actuators, controllers, and a user interface.

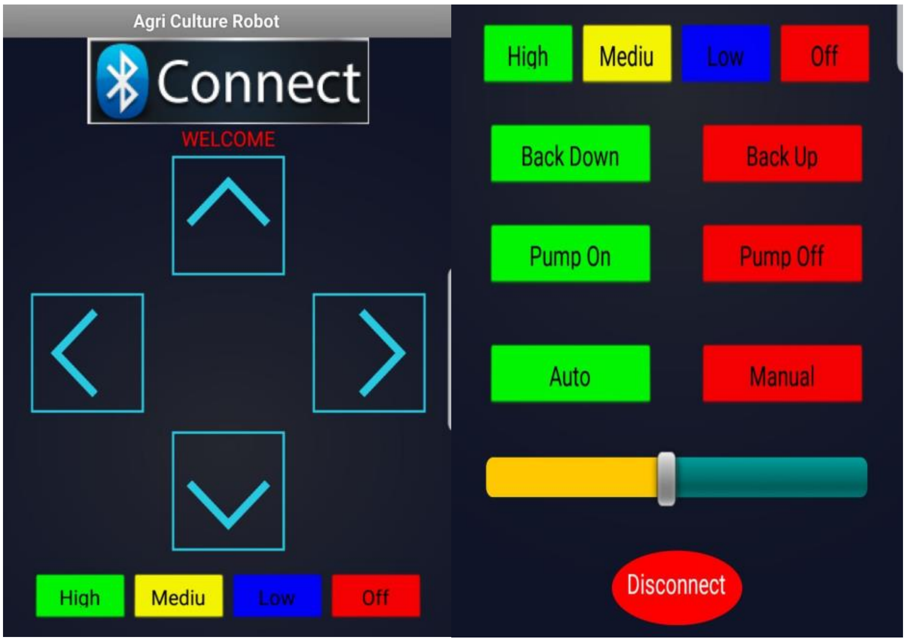


Command and control mechanism

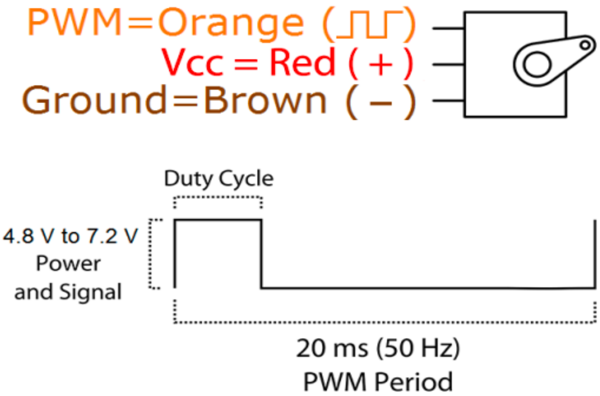
Each function on the robot has a name, allowing us to control it independently, and it is managed by a specially created program. A completely autonomous multipurpose seed-sowing robot must carefully consider its mechanical design, sensor capability, software control, and user interface. The mechanical structure of the robot, such as the chassis, wheels, drilling mechanism, seed tank, valve, covering mechanism, etc. The mechanical structure of the robot is sturdy, lightweight, and suitable for different soil conditions and seed types. The electronic components of the robot are compatible with each other and provide the necessary power and control for the robot, such as the Arduino board, Bluetooth module, DC motors, servomotors, sensors, batteries, solar panels, etc. Incorporate a power system that can sustain the robot's operation for extended periods. Consider options like rechargeable batteries or solar power, depending on the robot's size and energy requirements. The circuit of the robot, connects the electronic components to the Arduino board using wires, breadboards, resistors, capacitors, etc. The circuit should follow the schematic diagram and ensure proper connections and polarity.

The Arduino board uses the Arduino IDE (Integrated Development Environment), which is a software tool that allows writing and uploading code to the Arduino board. The code implements the control algorithm for the robot, which defines how the robot performs its tasks, such as moving, drilling, sowing, covering, etc. The code should also enable communication between the robot and the Bluetooth module using serial commands.

The application uses Android Studio and other software tools, which is a software program that runs on a smartphone or a remote controller and allows sending commands to the robot via Bluetooth. The application is a user-friendly interface that displays the status and parameters of the robot, such as speed, direction, depth, rate, etc. The Android application also allows to adjust these parameters according to the user's preference. Develop a user-friendly interface to program and control the robot. This can include a touchscreen display or a smartphone application that allows users to specify planting patterns, seed types, and other parameters.



Application

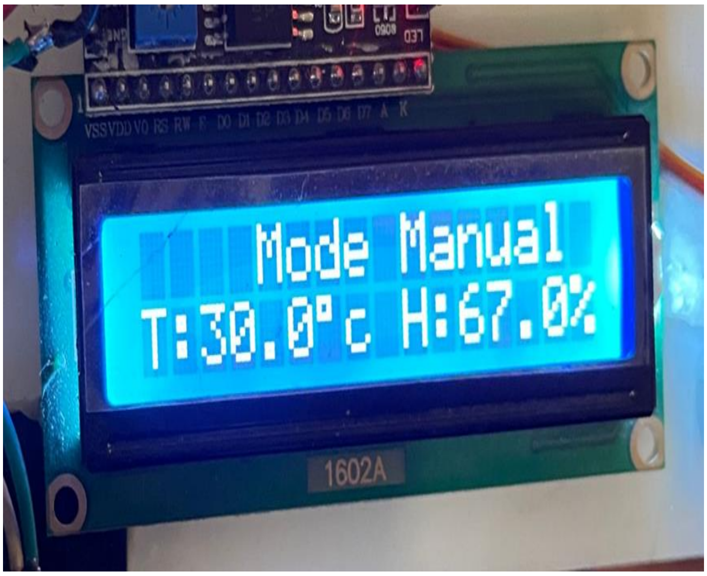


Metal gearing gives the High-Torque MG996R Digital Servo an extra-high 10kg stalling torque in a small compact. The MG996R is an improved version of the well-known MG995 servo. It has improved shock-proofing, a new PCB and IC control system, and other improvements that make it far more accurate than its forerunner. To increase dead bandwidth and centering, the gearing and motor have also been updated. The device includes a 30 cm long cable and a 3 pin 'S' type female header connection that is compatible with the majority of receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum, and Hitec. This basic servo with strong torque has a rotational range of around 120 degrees (60 in each direction).

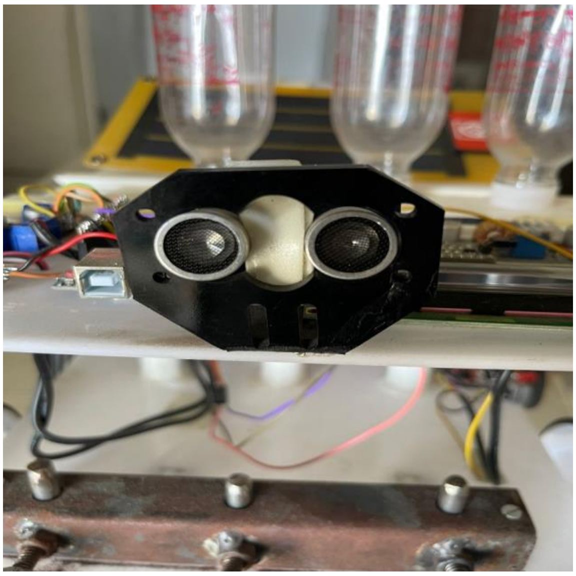
Bandwidth of 5 µs for a servo motor means that the motor will remain stationary when the control signal is within a range of 5 µs (microseconds) around its central position. In other words, if the input control signal falls within ±2.5 µs of the center position DC motors rated at 12V can be suitable for certain seed sowing applications, depending on the specific requirements of the seed-sowing robot and the size of the agricultural field. Here a 5-volt DC pump is likely used in the seed sowing robot for spraying water or other fluids to aid in the seeding process. The low voltage ensures safe operation, and the pump's design allows for precise and controlled spraying. The DHT11 temperature and humidity sensor is a widely used digital sensor that can measure both temperature and humidity

The HC-SR04 is an ultrasonic distance sensor commonly used in various robotics applications, including seed sowing robots for obstacle avoidance.

Sensor Integration: Arduino boards can interface with various sensors, such as proximity sensors, soil moisture sensors, GPS modules, and speed sensors. These sensors provide essential data to the Arduino control unit, allowing it to make decisions based on real-time field conditions.
Motor Control: The Arduino can control the DC motors, stepper motors, or servo motors used in the seed sowing robot. It interprets sensor data and navigational inputs to control the motors responsible for seed dispensing and robot movement.
which are likely used to create furrows or rows in the soil for sowing seeds. In this robot,



Digital display



HC-SR04 is an ultrasonic distance sensor:

the steel rods, with a diameter of 2.5 cm, would be inserted into the soil to create furrows at a depth of 10 cm. These furrows provide a proper environment for seed placement before the sowing process.

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4. Results

The slowest speed of 8.5 sec per feet is assumed on very uneven and rocky terrain, where the robot needs to move cautiously

Sowing Robot Speed on Different Land Types.

Land Type	Speed (second per feet)
Smooth and Flat	5
Slightly Uneven	6.5
Moderately Uneven	7
Rough and Bumpy	7.5
Hilly and sloped	8
Very Uneven and Rocky	8.5

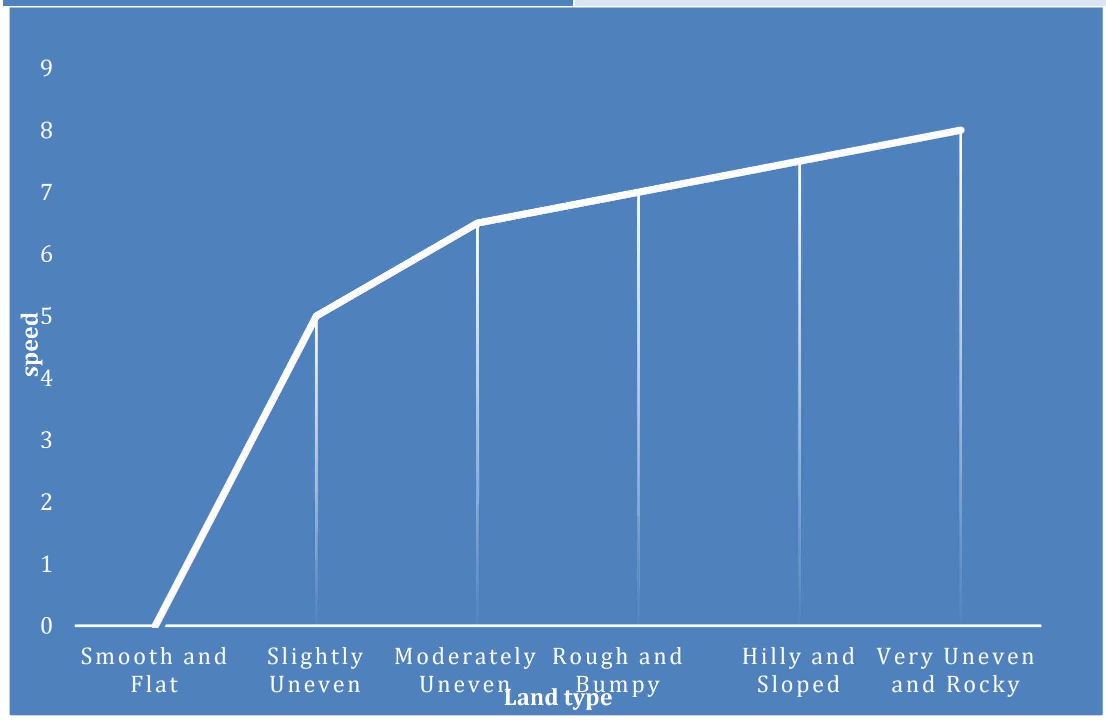


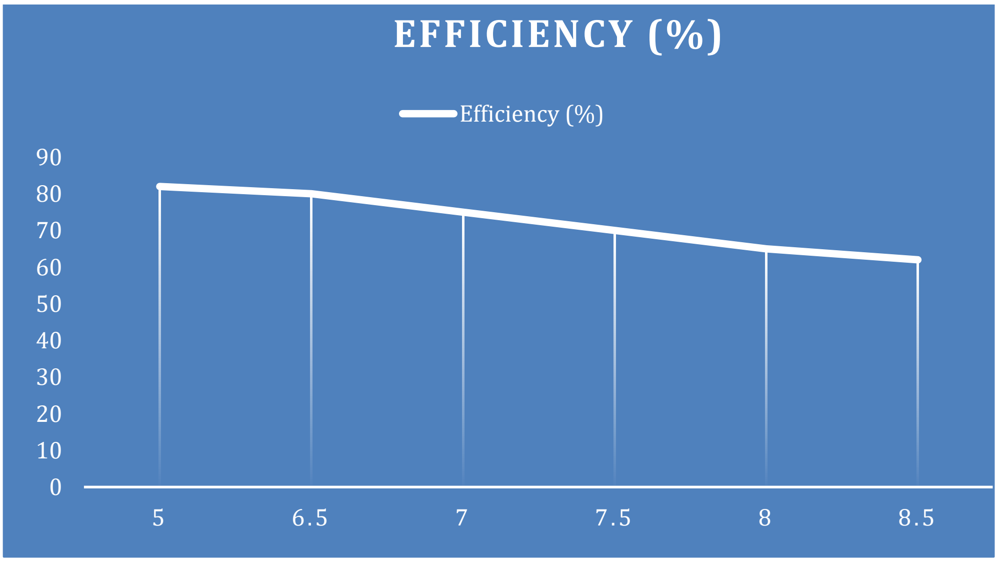
Figure 1 Graph: Between land type and speed.

Implementing voltage regulation mechanisms is important to prevent motor burnout and to optimize the robot's energy consumption. This ensures that the battery's energy is utilized efficiently without damaging the components.

Effect of 15V Battery Voltage on Sowing Robot Speed and Efficiency.

Battery Voltage (V)	Speed (second per feet)	Efficiency (%)
15V	5	82
15V	6.5	80
15V	7	75
15V	7.5	70
15V	8	65
15V	8.5	62

Graph: Between Efficiency and speed of robot.



To mitigate the effects of varying humidity and temperature, the robot may require self-protection mechanisms, such as water-resistant casings, temperature sensors, and cooling systems. Regular calibration of sensors and actuators based on environmental conditions can help maintain accuracy in seed distribution and navigation. Recording environmental conditions during experiments can help identify patterns and correlations between environmental factors and the robot's performance and seed distribution.

Table 1 Table: Speed Efficiency of Seed Sowing Robot with Varying Humidity and Temperature

Speed (second per feet)	Efficiency (%)	Humidity (%)	Temperature (°C)
5	80	50	45
6.5	75	55	35
7	70	65	30
7.5	65	70	27
8	62	72	25

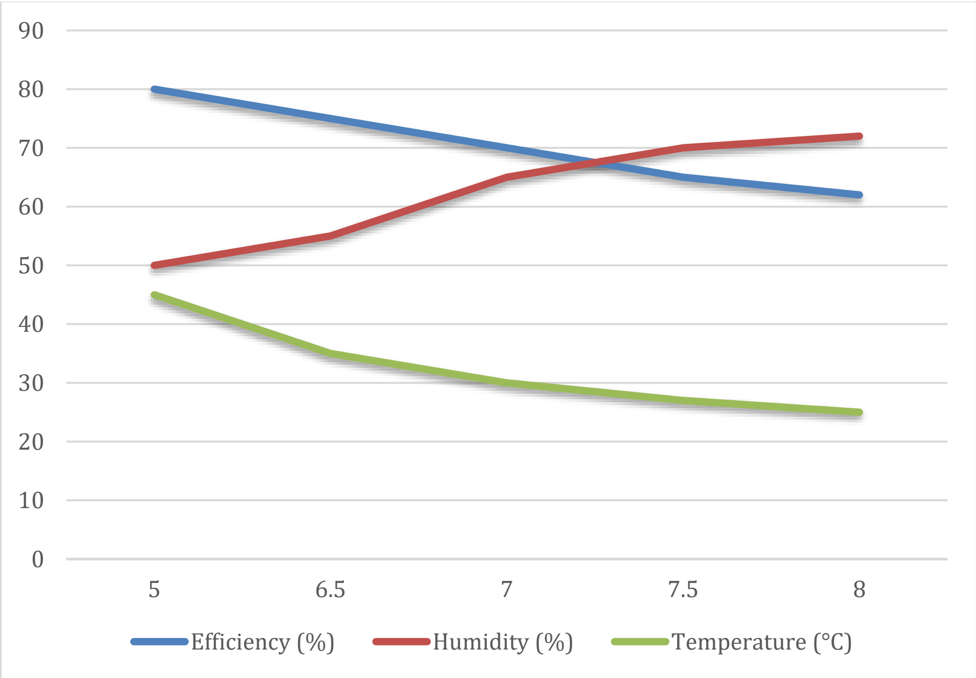


Figure 2 Graph: Relation between speed, humidity and temperature.

The MG996R is essentially an upgraded version of the famous MG995 servo, and features upgraded shock-proofing and connecting with Arduino system that make it much more accurate than its predecessor

Table 2 Table: Seed Sowing Robot Efficiency with Different Servo Motor Speeds

Servo Motor Speed (sec/60-degree	Speed (second per feet)	Efficiency (%)
5	5	80

6	6.5	75
6.9	7	70
7	7.5	65
7.2	8	62

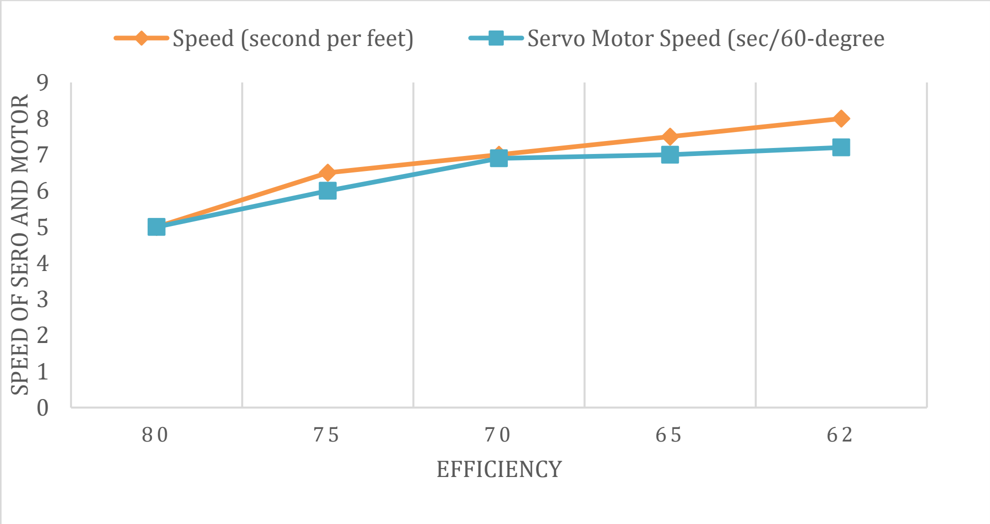


Figure 3 Graph: Between servo motor and speed of robot

The initial cost of setting up a solar panel system may be higher, but it can lead to long-term cost savings as the robot utilizes free solar energy for charging. Once installed, the ongoing operational costs are minimal.

Table 3 Table: Power, Efficiency, and Voltage of Sowing Robot.

Power (Watts)	Voltage (Volts)	Efficiency (%)
20	9	60
24	10	64
25	11	70
27	11.5	75

30	12	80

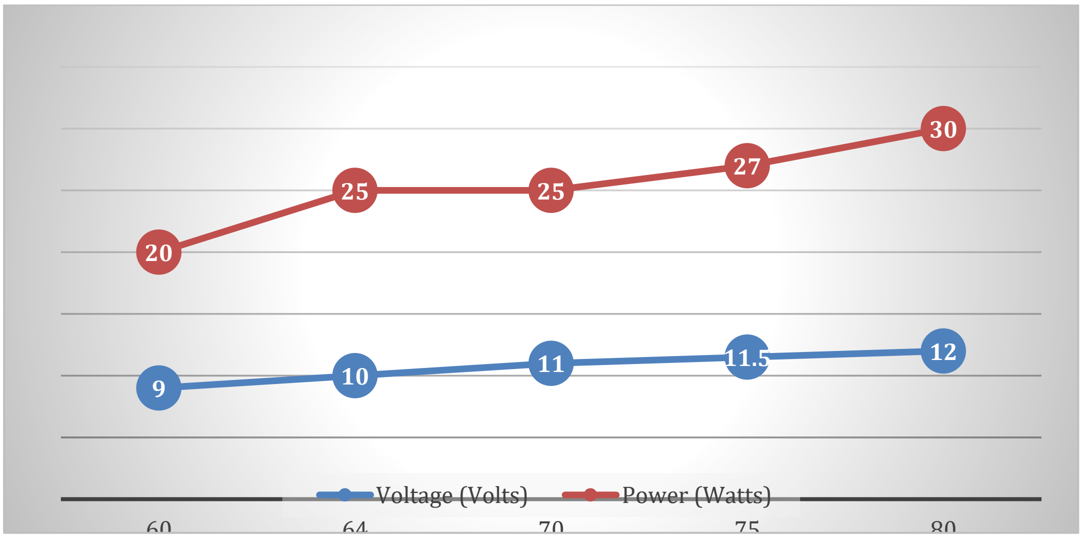


Figure 4 Graph: Voltage and power, efficiency of seed sowing robot.

5. Conclusions

Modern farming operations will undergo a radical change with the creation of an automated multipurpose agriculture robot. Farmers gain a great deal from this robot because it is made to do necessary jobs like spraying pesticides, weeding, checking soil, and planting seeds. The robot reduces the amount of human labor, improves precision, and shortens the time needed for different farming activities by automating these labor-intensive tasks.

By eliminating the need for physical labor and maximizing the use of resources like seeds, fertilizer, and pesticides, the robot also helps farming become more affordable.

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