



## DEVELOPMENT AND PERFORMANCE EVALUATION OF A MOTORIZED BATTERY-POWERED SPRAYER

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### **Abstract**

The development and application of automated sprayers in agricultural practices represent a significant advancement in precision farming technology. This project aims to design, fabricate, and evaluate a motorized battery-powered sprayer tailored to enhance pesticide and herbicide application efficiency and effectiveness. The system was incorporated with spraying attachments, DC battery (UPS-12V) and DC motor as prime mover for autonomous navigation capabilities to optimize spraying operations in diverse agricultural environments and reduce the dependency on the fossil fuels. The components of the sprayer were designed following the standard engineering design procedure. The forward speed studied for the optimization of the spray nozzles were 1.8, 0.99, and 0.75 m/s with a distance of 10 m at all instances. It was recorded from the experiments that the angle of inclination of 90° had the widest coverage area. The results also showed that at a particular speed the flow rate remained constant regardless of the angle of inclination. The flow rate also varies directly with the speed of operation of the sprayer. The optimization results revealed that the sprayer performed effectively at the combination of forward speed of 1.82 m/s and angle of inclination of 90° resulting in effective field capacity of the sprayer was 54.90 m<sup>2</sup>/s.

**Keywords:** *Flow Rate, Battery-powered, Optimization, Prime mover, Field capacity*

### **Introduction**

The rapid advancement of technology has had profound impacts across various sectors, including agriculture, where the need for efficient and effective tools is increasingly crucial. Among these tools, sprayers play a significant role in ensuring optimal application of pesticides, herbicides, and fertilizers (Wang *et al.*, 2022). Traditional sprayers, which often rely on manual labour or gasoline-powered engines, have served their purpose well but come with limitations such as high labour intensity, environmental concerns, and operational inefficiencies. In recent years, there has been a growing interest in developing more innovative, sustainable, and user-friendly solutions. One such innovation is the motorized battery-powered sprayer. Traditional manual spraying methods, utilized to distribute pesticides and herbicides, have often proven to be inadequate (Wayzode *et al.*, 2016; Raghava and Rajendra, 2020). Uneven distribution, wastage of chemicals, and potential environmental harm are the unwanted consequences of this age-old approach. In response to these challenges, there is a growing need for a revolutionary solution, an automated field sprayer equipped with remote control capabilities. The importance of efficient and

precise spraying in lawn maintenance is well-documented in the scientific literature. Studies have demonstrated the potential of advanced technologies to enhance the precision and efficacy of spraying. For instance, Mitchell *et al.* (2015) explored remote sensing techniques to evaluate sagebrush canopy nitrogen. While seemingly distant from the world of lawns, these remote sensing methodologies offer insights that can transform the understanding of nutrient dynamics and post-fire recovery, showcasing the transformative potential of cutting-edge technologies in the realm of lawn maintenance. The integration of computer vision methods, as exemplified by Wu *et al.* (2021), has proved instrumental in weed detection across various agricultural applications, including lawn maintenance. By harnessing computer vision, lawn sprayers can pinpoint and eliminate weeds with unparalleled accuracy. These studies spotlight the role of innovation in technology as a catalyst for precision and efficiency in spraying within the context of lawn care.

The development of a semi-automated lawn sprayer with remote control capabilities beckons the adoption of an interdisciplinary perspective.

Valuable insights can be gleaned from adjacent fields, shedding light on critical design and navigation aspects of the sprayer system (Michael *et al.*, 2020; Baltazar *et al.*, 2021). Savelli *et al.* (2017) have delved into the framing of grid cells and spatial cognition, which offer profound implications for the design and maneuverability of the semi-automated lawn sprayer. By drawing upon principles from spatial cognition, the sprayer system can navigate lawns with unparalleled precision, ensuring even distribution of pesticides. Studies focusing on advanced precision spraying systems for tree fruits, as exemplified by Mahmud *et al.* (2021), provide valuable lessons that can be extrapolated to optimize the semi-automated lawn sprayer's design. The ability to tailor spraying patterns to specific needs, as demonstrated in fruit tree cultivation, has direct implications for optimizing lawn maintenance. These interdisciplinary perspectives underscore the value of amalgamating knowledge domains to engineer innovative solutions for lawn maintenance.

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The transition from manual to motorized sprayers represents a significant leap forward in agricultural technology. Manual sprayers, while simple and cost-effective, often demand considerable physical effort and can lead to inconsistent application, affecting crop health and yield. Gasoline-powered sprayers, though more efficient in terms of labour, introduce issues related to fuel handling, emissions, and noise pollution (Wang *et al.*, 2022). The motorized battery-powered sprayer aims to address these challenges by integrating modern electric propulsion with a rechargeable battery system, offering a more environmentally friendly and user-centric alternative.

## Materials and Method

The development of a motorized battery-powered field sprayer was approached with a meticulous and comprehensive methodology. The research design served as the guiding blueprint for the entire project, delineating clear objectives and the methodology to be employed. In terms of materials, careful consideration was given to the selection and specification of each component, encompassing metals, plastics, electronic elements, and other crucial materials. The fabrication process, outlined step by step, provided a detailed account of the construction procedures, including welding, electronic component assembly, and other relevant fabrication steps. Rigorous testing procedures were implemented, with a focus on evaluating performance, efficiency, and safety in various scenarios. The collected data underwent thorough analysis, employing statistical methods and comparisons to benchmarks, resulting in meaningful insights.

The research that was designed for this project is experimental, with a primary focus on the fabrication and testing of a motorized field sprayer. This design has been strategically crafted to delve into the intricate process of constructing and evaluating a specialized vehicle tailored for agricultural field spraying purposes. At the core of the design is the incorporation of a wired remote-control technology, aimed at augmenting precision and efficiency in agricultural spraying practices. By integrating this advanced technology, the project aims to address the evolving needs of the agricultural sector, offering a solution that not only streamlines spraying processes but also contributes to enhanced accuracy and effectiveness in the application of agricultural inputs. This experimental approach underscores the commitment to innovation and practical applicability within the realm of agricultural machinery development.

## Conception of the Motorized Battery-Powered Sprayer

A motorized battery-powered sprayer prototype with an automated gun sprayer for vegetable crop applications was designed and built taking into account crop and machine parameters. The sprayer is primarily composed of a main frame, spray tanks, traction wheels, nozzles, DC motor, and flexible rubber hose. The main frame was placed on top and stands on two traction wheels, carrying the storage

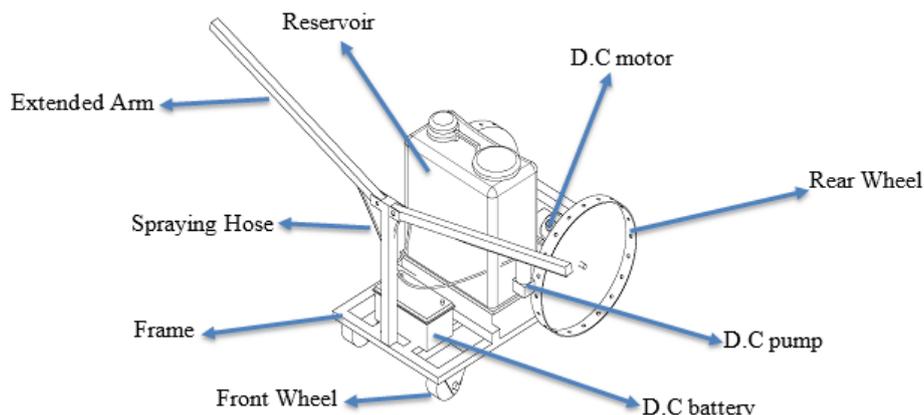


Figure 1: Conceptualized Isometric view of the Motorized Sprayer

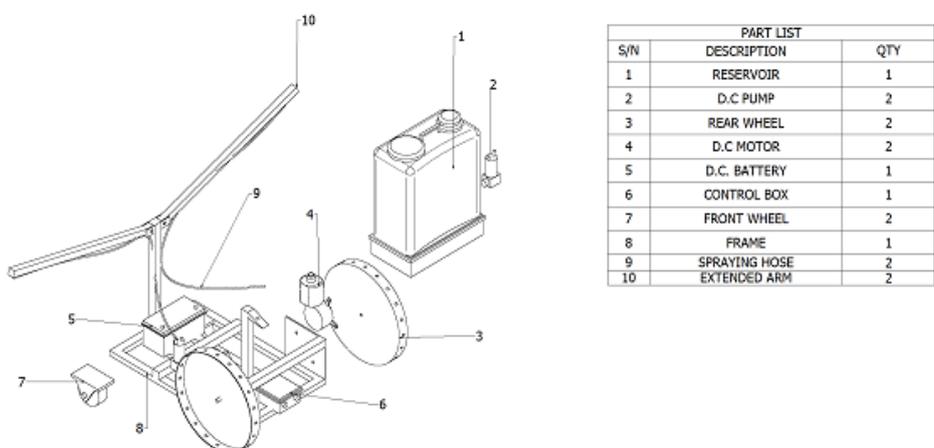


Figure 2: Conceptualized Isometric view of the Motorized Sprayer

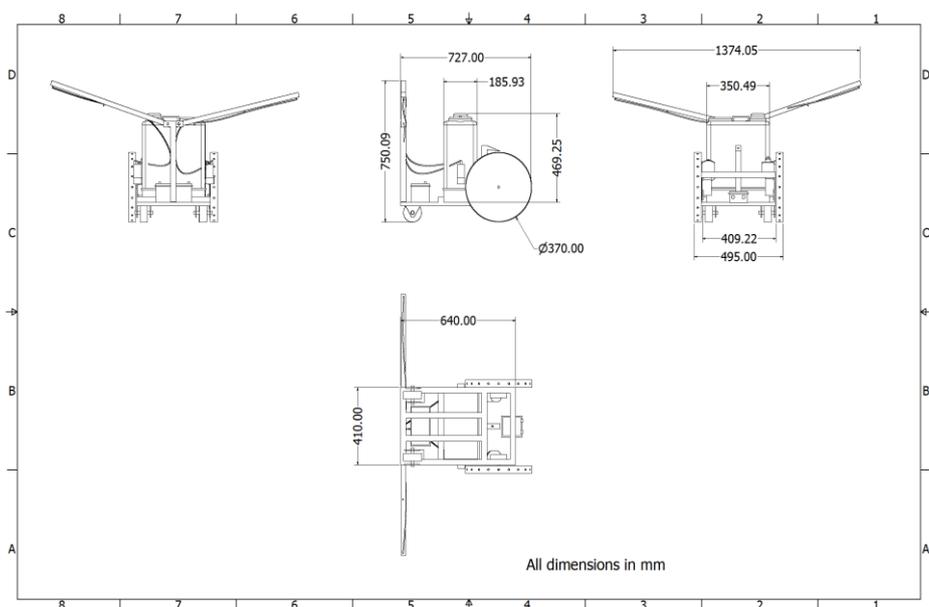


Figure 3: Orthographic projection of the battery-powered motorized sprayer

tanks and DC pumps with spraying nozzles; the tank was connected to the pump via flexible rubber hose distribution. The machine's schematic perspective is

displayed in Figures 1, 2 and 3. A 16-litre polypropylene chemical tank was used in order to minimize the need for frequent refills. The prime

mower (DC motor) drives the sprayer over the cultivated ground while the automated pump sprays the plot using an extended hose that is set perpendicular to the direction of motion. To operate the machine the operator just has to turn on the pump and the prime mower. The prime movers (two electric motors) are attached separately to the two rear wheels. These are powered by battery to enable the turning of the wheels. That is, every wheel at the back was driven separately. As soon as the wheel starts to move, the automatic pump turned on to operate the pumping action. A constant spraying was accomplished due to the operation of the DC pump which was designed to maintain a regular and steady working pressure on the discharge ends of the system and capable of moving the overflow back into the tank. The operation stopped when the prime mower stops. The machine was fabricated at the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure (FUTA).

### Materials

The construction of the motorized field sprayer involved a thoughtful selection of materials for various components (Table 1). While certain parts, such as motors, wires, and bearings, utilized standard materials, distinctive choices were made for critical elements. The frame, serving as the foundational structure of the vehicle, was crafted from square steel pipes to ensure robustness and stability. The rear wheels were fashioned from cost-effective yet durable steel sheets, shaped into circles to efficiently bear the load imposed on them. The front wheels, designed for enhanced maneuverability, were constructed using heavy-duty steel and solid rubber mixed with PVC. The liquid storage unit was composed of PVC (polyvinyl chloride), chosen for its suitability in containing liquids. Additionally, the liquid transfer tubes were crafted from flexible rubber, providing the necessary adaptability for seamless functionality. This meticulous selection of materials for each component reflects a balanced consideration of factors such as cost-effectiveness, durability, and functionality in the design and construction of the motorized field sprayer.

### Design Analysis

The design process involves comprehensive engineering analysis, material selection, and prototype development to ensure robustness and reliability in real-world applications. Throughout the project, extensive testing and validation procedures are conducted to assess the performance, accuracy, and reliability of the automated sprayer system. Parameters such as spraying coverage, uniformity, and navigation accuracy are evaluated under various operating conditions to ensure optimal functionality and efficiency.

### Determination of the volume of the tank

The volume of the sprayer tank was determined using Equation 1.

$$V = hlb \quad (1)$$

Where  $v$  is the volume ( $m^3$ ),  $h$  is the height (m),  $l$  is the length (m) and  $b$  is the breadth (m).

### Determination rolling resistance (FR)

Equation 2 was used to compute the rolling resistance (FR)

$$FR = CR \times W \quad (2)$$

Where: FR is the rolling resistance or rolling friction (N), CR is the rolling resistance coefficient, which is dimensionless, coefficient of rolling resistance  $CR=0.017$  according to Poratkar and Raut (2013).

### Determination of the power requirements

The motorized battery-operated spraying performance rate per day was computed year-round by calculating the electrical power utilized in the machine system's equipment (pt) per W. The pump power and the motor hours are included in the energy usage. The power consumption was calculated using Equations 3-4 as follows:

$$P_c = P_{c(motor)} + P_{c(pump)} \quad (3)$$

$$P = FT \times \frac{v}{\eta} \quad (4)$$

Where,  $P$  is the engine power (W) required to propel the spray vehicle,  $FT$  is the total force required (N),  $v$  is the velocity of the vehicle ( $ms^{-1}$ ),  $\eta$  is the efficiency of the wheel traction.

### Fabrication Process

The fabrication process of the field sprayer was a meticulously planned and executed endeavour, involving a systematic step-by-step construction approach. This section delves into the intricacies of the fabrication, offering a comprehensive account of the methods employed throughout the sprayer's assembly. Each step was carefully considered, with a focus on precision and functionality. The construction process initiates with the assembly of the frame, where precision measurements and welding are employed to guarantee stability and robustness. Wheel construction follows suit, with the rear wheels fashioned from cost-effective yet durable steel sheets shaped into circular forms. The front wheels, designed for enhanced maneuverability, utilize heavy-duty steel. The liquid storage unit, an integral part of the sprayer, was



**Plate 1:** The Assembled Battery Powered Sprayer



**Plate 2:** The Assembled Battery Powered Sprayer



**Plate 3:** The sprayer In-field experiments

carefully crafted to seamlessly integrate into the overall structure. A pivotal component of the fabrication process was the creation of the liquid transfer system, where flexible rubber tubes were employed to facilitate adaptability during spraying. The integration of motors and wiring comes next, with a keen focus on ensuring proper functionality

and alignment with the control system. The semi-automatic control system, incorporating sensors and programming, was then seamlessly integrated, paving the way for automated spraying processes. Once the various components are assembled, a thorough testing and calibration phase ensues. This crucial step ensures that the sprayer operates with

**Table 1:** Components and Materials

S/N	Components	Material used
1	Frame/ Body	Coated steel square pipes
2	Rear Wheels	Circular shaped steel sheets
3	Front Wheels	Heavy-duty steel and solid rubber
4	Storage unit	PVC (Polyvinyl Chloride)
5	Liquid Transfer Tubes	Flexible rubber
6	Manufactured components	Manufacturer Standard Material

precision, efficiency, and accuracy. The final assembly brings together all the meticulously crafted components into the ultimate configuration of the motorized field sprayer. Attention was given to proper alignment and secure fastening to guarantee the sprayer's operational integrity.

### Performance Evaluation

Two sets of tests were conducted to assess the performance of the sprayer:

- a. Laboratory trials and
- b. In-field experiments.

The purpose of the laboratory tests was to ascertain the impact of the machine and surroundings on the machine configuration (Plate 2). These variables include soil resistance to motion, wind direction, and air speed. The real data on the total spraying performance was obtained through the in-field testing. Using a stop watch, the amount of time needed to spray the fluid along the whole length of the row was noted. The sprayer tank's graduations was used to determine the quantity (volume) of liquid needed to spray each row of crops. Each row's length was measured with a measuring tape. The real field capacity was calculated taking into account the time loss resulting from turning as well. The whole spraying field's area was measured. The table with the corresponding volume and time readings for every row was created. In order to record the discharge rate and total field covered per time, the data was recorded at different spray width levels using a stop watch (Plate 3). The spraying was achieved through the agitation of the incorporated pump that pumped the liquid through the orifices made along the equal and predetermined distances on the spraying hose.

### Results and Discussion

The results from this study offer valuable insights into the operational dynamics of the spraying machine, shedding light on how different parameters affect its performance. During the testing phase, three iterations were conducted to evaluate the spraying and movements, with each iteration featuring varying angles of the spraying handles. The evaluation process utilizes the following parameters to assess the performance and its effectiveness (Table 2):

- i. **Distance:** The machine undergoes testing on a 10-metre (10 m) long lawn, ensuring a consistent and standardized distance for all test runs.
- ii. **Speed:** This parameter represents the velocity achieved by the machine during different iterations, derived from the time taken to cover the fixed distance of 10 metres.
- iii. **Angle of Spraying Handles:** The movable spraying handles responsible for holding the tubes that dispensed the liquid and are positioned at different angles during each iteration to assess their impact on coverage area and distribution patterns.
- iv. **Spraying Distance:** This parameter refers to the maximum distance achieved by the sprayed liquid at each designated spraying angle. Spraying distance was measured and recorded for each iteration to evaluate coverage area and potential overlaps or gaps.
- v. **Flow Rate:** The volume of liquid discharged per unit of time during the spraying process represents the flow rate. This parameter is crucial for determining the application rate and ensuring consistent and uniform coverage across the target area.

### Design Analysis

This analysis focuses on evaluating the spraying coverage area based on the spraying distance and angle. The coverage area is expected to be wider at larger spraying distances and angles.

Table 3 shows that at a distance of 30.14 m, coverage area of 301.4 m<sup>2</sup> and an angle of 90°, the coverage area was seen to be the widest. At spraying distance of 21.27 m with coverage area of 212.7 m<sup>2</sup> and an angle of 45°, the coverage area was recorded to be wide, and at a distance of 9.20 m with area of 92.0 m<sup>2</sup> and an angle of 180°, the coverage area was marked narrow. Hence for the combinations of the spraying distance and the area covered, the sprayer when operated at the spraying angle of 90° performed best by covering the widest area.

**Table 2:** Evaluation Parameters for a distance of 10 m

Iterations	Speed (m/s)	Time (s)	Spraying angle (°)	Volume (ml)	Spraying Distance (m)	Area (m <sup>2</sup> )	Flow Rate (ml/s)	Application Rate (ml/m <sup>2</sup> )	Field Capacity (m <sup>2</sup> /s)
1	1.82	5.49	45	42	21.27	212.7	7.65	0.20	38.74
2	1.82	5.49	90	42	30.14	301.4	7.65	0.14	54.90
3	1.82	5.49	180	42	9.20	92.0	7.65	0.46	16.76
4	0.99	10.10	45	53	21.27	212.7	5.23	0.25	21.06
5	0.99	10.10	90	53	30.14	301.4	5.23	0.18	29.84
6	0.99	10.10	180	53	9.20	92.0	5.23	0.58	9.11
7	0.75	13.33	45	57	21.27	212.7	4.28	0.27	16.20
8	0.75	13.33	90	57	30.14	301.4	4.28	0.19	22.96
9	0.75	13.33	180	57	9.20	92.0	4.28	0.62	7.01

**Flow Rate and Volume Analysis**

This analysis examines the relationship between volume, flow rate, application rate and other parameters like speed and angle (Table 4).

At a constant speed of 1.82 m/s, the flow rate remained constant at 7.65 ml/s regardless of the angle of inclination. At lower speeds of 0.99 and 0.75 m/s, decrease flow rates were recorded as 5.23

inversely proportional to speed of operation. It was also evident that in all the combinations of the test speeds, the best application rate of 0.14, 0.18 and 0.19 ml/m<sup>2</sup> were recorded for 1.82, 0.99 and 0.75 m/s for the inclination angle of 90°.

**Conclusions**

The findings from this study provide comprehensive insights into the performance of the spraying

**Table 3:** Coverage Area at different Angles

Iteration	Spraying Distance (m)	Area (m <sup>2</sup> )	Angle (°)	Expected Coverage Area
1, 4, 7	21.27	212.7	45	Wide
2, 5, 8	30.14	301.4	90	Widest
3, 6, 9	9.20	92.0	180	Narrow

**Table 4:** Evaluation Parameters of the Sprayer

Iteration	Speed (m/s)	Angle (°)	Volume (ml)	Flow Rate (ml/s)	Application Rate (ml/m <sup>2</sup> )	Field Capacity (m <sup>2</sup> /s)
1-3	1.82	45, 90, 180	42	7.65	0.20, 0.14, 0.46	38.74, 54.90, 16.76
4-6	0.99	45, 90, 180	53	5.23	0.25, 0.18, 0.58	21.06, 29.84, 9.11
7-9	0.75	45, 90, 180	57	4.28	0.27, 0.19, 0.62	16.20, 22.96, 7.01

and 4.28 ml/s respectively which were also constant irrespective of the angle of inclination, indicating a potential and direct relationship between speed and flow rate. The same trend was recorded for the field capacity, as the speed increases the field capacity also increases. The direct proportionality between the speed and the flow rate is in agreement with the findings of Soyoye (2020) where it was recorded that the metering speed is directly proportional to the discharge rate of a locally developed maize planter. Lower flow rates were observed at lower speeds. It is also an evidence from the Table 4 that, the application rate increased as the speed decreased. At the speeds of 1.82, 0.99 and 0.75 m/s, the application rates were 0.20, 0.25 and 0.27 ml/m<sup>2</sup> respectively for 45° inclination angle. The same trends were recorded for the inclination angles of 90° and 180° respectively, this shows that the application rate is

machine under varying operational parameters. The evaluation focused on key factors including speed, spraying angles, spraying distance, and flow rate, with the objective of determining their impact on the machine's effectiveness.

- i. **Spraying coverage and angle:** The analysis of spraying coverage demonstrated that the machine achieved the widest coverage area when operated at a spraying angle of 90 degrees. At this angle, the machine covered an area of 301.4 m<sup>2</sup> with a spraying distance of 30.14 meters, indicating optimal performance in terms of area coverage. Conversely, at a 180-degree angle, the coverage area was the narrowest, highlighting the importance

of angle adjustment in achieving desired coverage.

- ii. **Flow rate and volume analysis:** The relationship between speed and flow rate was evident throughout the study. At higher speeds (1.82 m/s), the flow rate remained constant at 7.65 ml/s, regardless of the spraying angle. However, as the speed decreased, both the flow rate and field capacity declined, aligning with the observed direct proportionality between speed and flow rate. Additionally, the application rate was found to be inversely proportional to the speed, with the highest application rates recorded at lower speeds.
- iii. **Overall Performance:** The study underscores that the machine's performance is highly sensitive to the chosen spraying angle and speed. For maximizing coverage area and ensuring effective application, operating the machine at a 90° angle of inclination with moderate speeds appears to be the most effective strategy. This setup provides a balance between coverage area and application rate, ensuring both efficiency and uniformity.

## References

- Baltazar, A. R., Santos, F. N. D., Moreira, A. P., Valente, A. and Cunha, J. B. (2021). Smarter robotic sprayer system for precision agriculture. *Electronics*, 10(17), 2061-2076.
- Mahmud, M. S., Zahid, A., He, L., and Martin, P. (2021). Opportunities and possibilities of developing an advanced precision spraying system for tree fruits. *Sensors*, 21(9), 3262-3291.
- Michael, C., Gil, E., Gallart, M., and Stavrinides, M. C. (2020). Influence of spray technology and application rate on leaf deposit and ground losses in mountain viticulture. *Agriculture*, 10(12), 615-633.
- Mitchell, J. J., Shrestha, R., Spaete, L. P. and Glenn, N. F. (2015). Combining airborne hyperspectral and LiDAR data across local sites for upscaling shrubland structural information: Lessons for HypSIRI. *Remote Sensing of Environment*, 167, 98-110.
- Poratkar, S. H. and Raut, D. R. (2013). Development of multinozzle pesticides sprayer pump. *International Journal of Modern Engineering Research*, 3(2), 864-868.
- Raghava, M. and Rajendra, D. (2020). Design and fabrication of dual power sprayer. *International Research Journal on Advanced Science Hub*, 2(7), 15-23.
- Savelli, F., Luck, J. D., and Knierim, J. J. (2017). Framing of grid cells within and beyond navigation boundaries. *Elife*, 6(1), 1-29.
- Shan, C., Wang, G., Wang, H., Xie, Y., Wang, H., Wang, S., Chen, S. and Lan, Y. (2021). Effects of droplet size and spray volume parameters on droplet deposition of wheat herbicide application by using UAV. *International Journal of Agricultural and Biological Engineering*, 14(1), 74-81.
- Soyoye, B. O. (2020). Effect of Metering Speed and Hopper Capacities on the Discharge and Application Rates of a Locally Developed Maize Planter. *Science & Technology*, 6 (21), 62-70.
- Wang, C., Liu, Y., Zhang, Z., Han, L., Li, Y., Zhang, H., Wongsuk, S., Li, Y., Wu, X. and He, X. (2022). Spray performance evaluation of a six rotor unmanned aerial vehicle sprayer for pesticide application using an orchard operation mode in apple orchards. *Pest Management Science*, 78(6), 2449-2466.
- Wayzode, P. B., Umale, S. R., Nikam, R. R., Khadke, A. D. and More, H. (2016). Design and Fabrication of Agricultural Sprayer, Weeder with Cutter. *International Journal of Research Advent Technology*, 340-344.
- Wu, Z., Chen, Y., Zhao, B., Kang, X. and Ding, Y. (2021). Review of weed detection methods based on computer vision. *Sensors*, 21(11), 3647-3677.