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Sensor-Based System for Mechanised Oil Palm Herbicide Spraying

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Abstract: The application of an electronic control system embedded in machinery for oil palm plantation operation is a relatively new concept. The application is currently being pursued to overcome several issues and concerns, such as reducing workforce requirements, increasing productivity, and improving effective chemical utilisation. Technologies are revolving, and IR4.0 components are cost-effective to be embraced in the field. A study was carried out to evaluate the performance of a sensor-spraying system attached to a three-wheeler prime mover. A Lidar sensor was used for palm circle spraying activity. An average 25% chemical reduction was obtained by embracing the sensor-spraying compared to a manually triggered system. The technology's effective cost is about RM 3 per ha with almost 30 ha per day coverage area. Integrating the system with IoT provides traceability of the activity on a web-based application. Thus, the system could enhance the standard operating procedure of chemical spraying in the field. The Lidar spraying system could provide better operational cost savings, reduce chemical consumption, increase worker productivity, provide a better monitoring system, and reduce labour requirements for oil palm fields' general upkeep activity.

Keywords: sensor; spraying; productivity; palm mechanisation

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1. Introduction

Palm oil is vital to Malaysia's economy as it provides national income, job creation, nutrition sources, and many more (Parveez *et al.*, 2022). In the palm oil upstream process, fresh fruit bunches are produced with a national average of 16–19 tonnes per ha per year. Recently, production has been hampered by the scarcity of labour, which could be overcome by adopting mechanisation and automation practices. Technologies were available for most of the field activities. However, these technologies depend significantly on the significance of terrain, soil type, and other environmental factors. Besides that, economic viability is a concern. In addition, excessive utilisation of chemical input with a low effective rate could harm the environment.

Herbicide spraying is a common technique employed for weed control in the oil palm field (Shariff & Rahman, 2008). Chemicals are sprayed on targeted areas to remove unwanted weeds. Thus, it could avoid nutrient intake competition with the palms and prepare the field for other activities. Typically, the herbicide is sprayed three to four rounds a year. Technologies vary from manual knapsacks to advanced sprayer systems attached to a vehicle such as a tractor. Advancement to the sprayer is by utilising a sensor to activate the pump or an automatic function spraying (Stover, 2002).

Several sensors are available for herbicide spraying, such as ultrasonic, infrared, and others. Studies have reported that sensors-based spraying produced many benefits, such as reducing off-target spray, reducing workers' requirements, reducing chemical and water consumption, and improving work productivity (Soitinaho *et al.*, 2022). However, specific sensors such as ultrasonic and infrared are unsuitable as their deflection angles are extensive, making unnecessary detection and producing waste (Mahmud *et al.*, 2021).

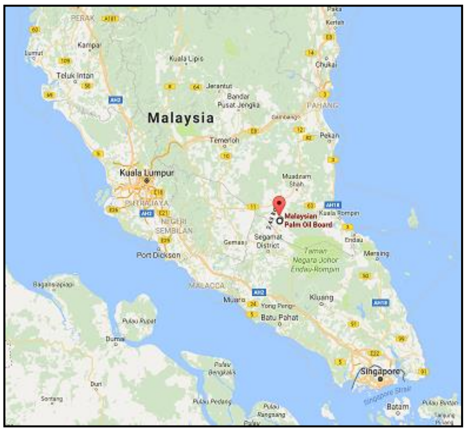
Light Detection and Ranging (Lidar) sensors have been studied for their application in automatic spraying. It is more effective than ultrasonic and infrared, using light waves from a laser instead of radio or sound waves. Two types of Lidar: 2D and 3D Lidar (Kurashiki *et al.*, 2021). The 2D illuminates a single beam of light to the target. It is lighter than the 3D types and suitable for outranging and detecting applications. Meanwhile, the 3D Lidar emits three light rays in various directions for 3D mapping and scanning functions.

The 2D Lidar is preferable for herbicide spraying applications. The sensor illuminates the light to collect information on the target's distance. Besides that, light absorption and reflection of the target could differentiate the type of materials that are not considered a target, such as low-hanging fronds or vertical poles. A processor will handle the information to control the actuator or other end-effector, such as the pump and nozzle. Thus, spraying volume could be managed according to real-time data received from the sensor. The speed of the spraying vehicle also plays a vital part in producing a good spraying volume in the targeted area and should correlate with the 2D Lidar sensor.

2D Lidar sensors attached to a field vehicle for herbicide spraying in an oil palm plantation in Malaysia are expected to reduce herbicide utilisation in the field. Besides that, IR4.0 components could produce traceability requirements on the herbicide application to ensure safe and sustainable operation in the area. Furthermore, IR4.0 technologies are cost-effective and can be embraced in the field.

2. Materials and Methods

A trial was conducted by attaching the 2D Lidar sensor system to a three-wheeler machine for oil palm weedicide operation. The test was conducted at MPOB Keratong research station in Muadzam Shah, Pahang. The geographical coordinates of the site are 2^0 46' 15.43" N latitude and 102^0 54' 53.18" E longitude, as depicted in Figure 1. The condition of the test site is primarily undulating, midland-type soil, and it is equipped with a farm mechanisation research facility. The selected area was divided into a few blocks where activities and the location of the field test could be measured and identified. The chosen research farm comprised a 70-ha area.



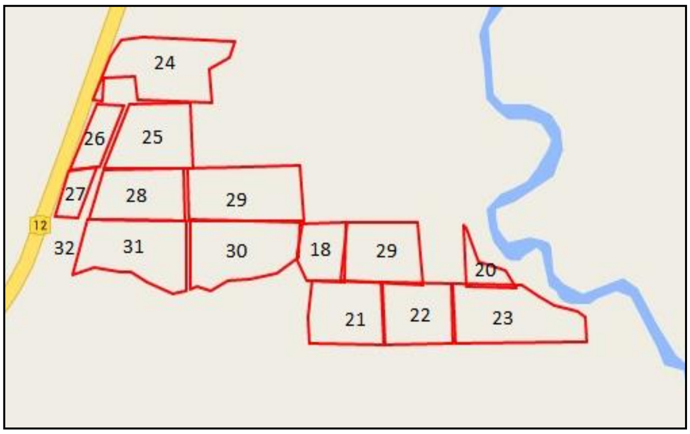


Figure 1. Location and block of the research area.

Two prototypes were prepared for the test (Figure 2). A sprayer machine was installed with a LiDAR sensor and an electronic system, as depicted in Figure 3 (schematic diagram of the components installation). Table 1 indicates the component sourcing information, while the other machine was without the system to act as a control. Lidars were installed on both flanks of the first machine. 2D lidars illuminated the target with a laser, and then the reflected light was analysed. Based on the distance and absorption of the laser, LiDAR will send a signal to the controller to activate the water pump and control valve. A speed regulator was also installed to enable the spraying volume to match vehicle speed; thus, a more accurate dose of the chemical could be sprayed. This function could reduce chemical wastage and improve environmental protection. The system records the spraying activity, and results can be monitored from a developed application, as depicted in Figure 4. The required information is recorded in a portable storage and then transmitted to the system designed. The spray output was recorded using a specific flow sensor attached to all pumps.

Figure 2. Test vehicle with Lidar Sensor

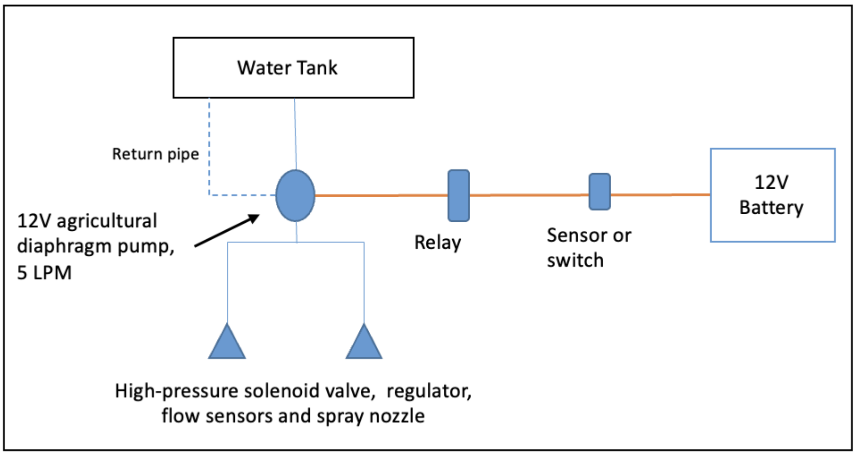


Figure 3. Simple schematic diagram of the setup.

Table 1. Component Sourcing

Components	Manufacturer / Distributor	Model No.
LiDAR Sensor	DF Robot, China	TFmini-i LiDAR Sensor (12m)
Controller & Speed Regulator	Cytron Technologies	Arduino Uno
Water Pump	Good Pumps, China	12V Diaphragm 6 L/Min 130 PSI
Control Valve	SPLT Consult	Irrigation Solenoid Valve NC
Flow Sensor	DF Robot, China	SEN0217

The operator was required to activate the switch for a manually triggered system when the palms were exactly on his right shoulder and shut it off when the vehicle was between two palms. The method of calculating spray volume was based on a previous study (Bakri *et al.*, 2019) and depicted in Equation 1 as follows:

$$A = c \times {}^{1}/_{a} \times {}^{1}/_{b} \tag{1}$$

Where A is the spraying volume (L/ha), a is the spray width (m), b is the average vehicle speed (km/hr or m/s), and c is the spray out (L/minute). Spray width is obtained by measuring the reach of the water spray length and was timed with the distance of the vehicle moved while spraying.

An economic assessment based on the ASABE standard was conducted to investigate further its effectiveness (Azwan *et al.*, 2016). The study will provide insights into its economic effectiveness compared to manual practice as a controlled benchmark. The viability of the technology in terms of technical and financial parameters could be assessed. The input parameter of the assessment is depicted in Table 2. The average purchase price and effective field capacity will be translated into depreciation and the total spraying cost. The machine life was assumed to be five years, with a 100% availability factor. ASABE methodology requires all parameters to be calculated hourly for the study.

Table 2. Assumption of the Economic Analysis

	Smart Sprayer	Knapsack Sprayer
The average purchase price per unit, RM	20,000	1,000
Effective field capacity, ha / hr	3	0.5

3. Results and Discussions

The test was conducted on a field since the spraying system must detect the palms for self-activation. The spraying volume with and without the Lidar system is depicted in Tables

3 and 4. The Lidar system could reduce water/chemical consumption by an average of 44 L/ha or about 25%, with 90% to 98% Lidar effectiveness based on 5%–10% absorption sensitivity. It was observed that the higher the vehicle speed, the lesser the differences in spray volume between both conditions. It indicates that the optimal speed was about 10 km/hr for the selected pump pressure and type of nozzle used in this trial. It was due to the chemical manufacturer's recommendation of the chemical volume per palm and the results indicated within the allowable dosage for practical chemical application (Ishak *et al.*, 2011; Shariff & Rahman, 2008).

Table 3. Sprayer without Lidar (Manual switch)

Pump Pressure (Bar)	Nozzle Flow Rate (L/Min)	Vehicle Speed (Km/hr)			
		5	**10**	**15**	**20**
		Spraying Volume (L/Ha)			
3	3	63	58	52	47
4	2.5	70	63	57	51

Table 4. Sprayer with Lidar (Automatic Spraying)

Pump Pressure (bar)	Nozzle Flow Rate (L/min)	Vehicle Speed (Km/h)			
		5	**10**	15	20
		Spraying Volume (L/ha)			
3	3	16	11	9	7
4	2.5	21	18	15	11

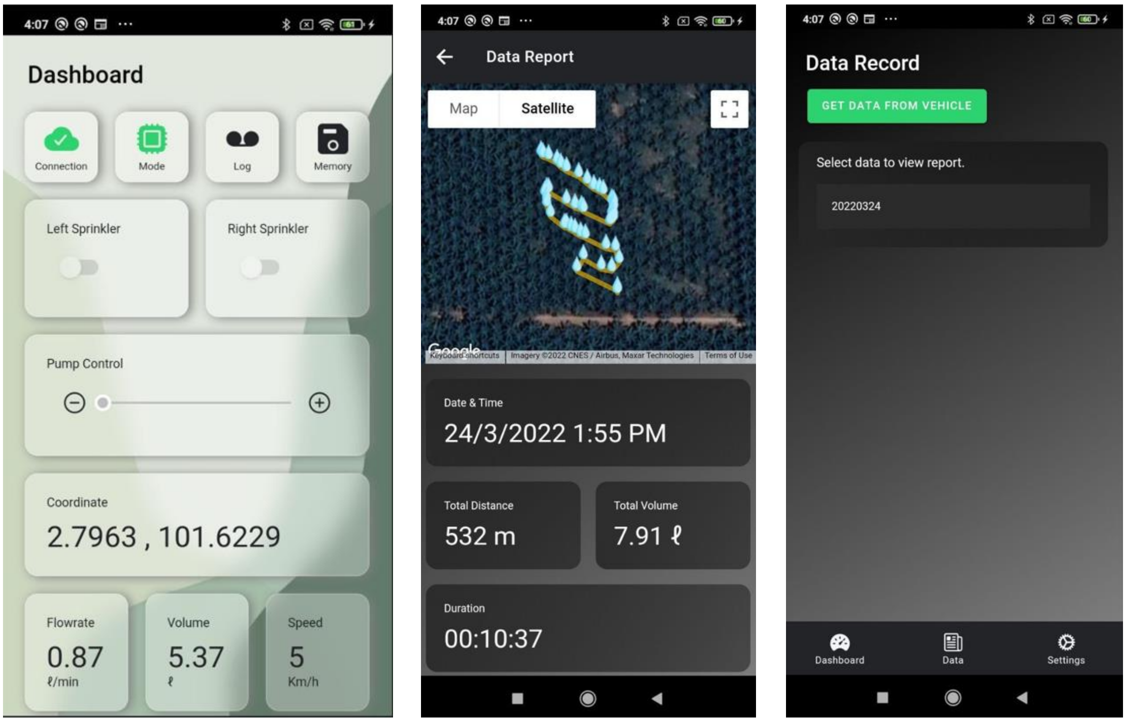
Based on the vehicle speed, the coverage of spraying with the Lidar sensor was estimated to be up to 30 ha per day. It was a conservative value or minimum level of adequate capacity since it could cover a larger area.

Benchmark data on the knapsack sprayer was made as a comparison. A simple operational cost analysis was conducted and tabulated in Table 5. The Lidar sprayer's operating cost was less than RM 3 per ha compared to the threefold cost of using a manual knapsack sprayer. The reason was justifiable based on previous MPOB experience evaluating the spraying machine (Azwan *et al.*, 2019).

Table 5. Economic Analysis

	Smart- Sprayer	**Knapsack Sprayer**
Depreciation cost, RM/hr	0.85	negligible
Repair and maintenance cost, RM/hr	1.25	negligible
Fuel/Energy consumption cost, RM/hr	0.6	negligible
Operator cost, RM/hr	5	5.00
Total spraying operation cost, RM/hr	**7.7**	**5**
Total spraying cost, RM/ha	**2.57**	**10**

The calibration table is essential for field operators as a reference in actual field operations to estimate chemical requirements for the weedicide activity. Proper work procedures will enhance its effectiveness and for better monitoring. Besides that, a better operational plan could be established to cater to the traceability of the operation as location and spraying volume can be mapped. A simple web-based application was set up to provide the required report, as in Figure 4. Integrating IoT in the plantation is a key to sustainable agriculture practices.



(a) (b) (c)

Figure 4. Information recorded (a); mapping of activity (b); The record is kept in the system (c)

4. Conclusions

The lidar-based spraying system has been proven to improve effectiveness in herbicide spraying activity in oil palm fields. It could speed up the process, attract locals to work at the plantation and increase sustainable development. Sustainable development could be increased due to the tracing and monitoring process, especially with the integration of IoT. The system could also provide cost-effective applications compared to traditional methods and with fewer activity requirements for the workers.

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Conflicts of Interest: The authors declare no conflict of interest

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