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Ergonomic investigation on spraying task performance in paddy farming activities

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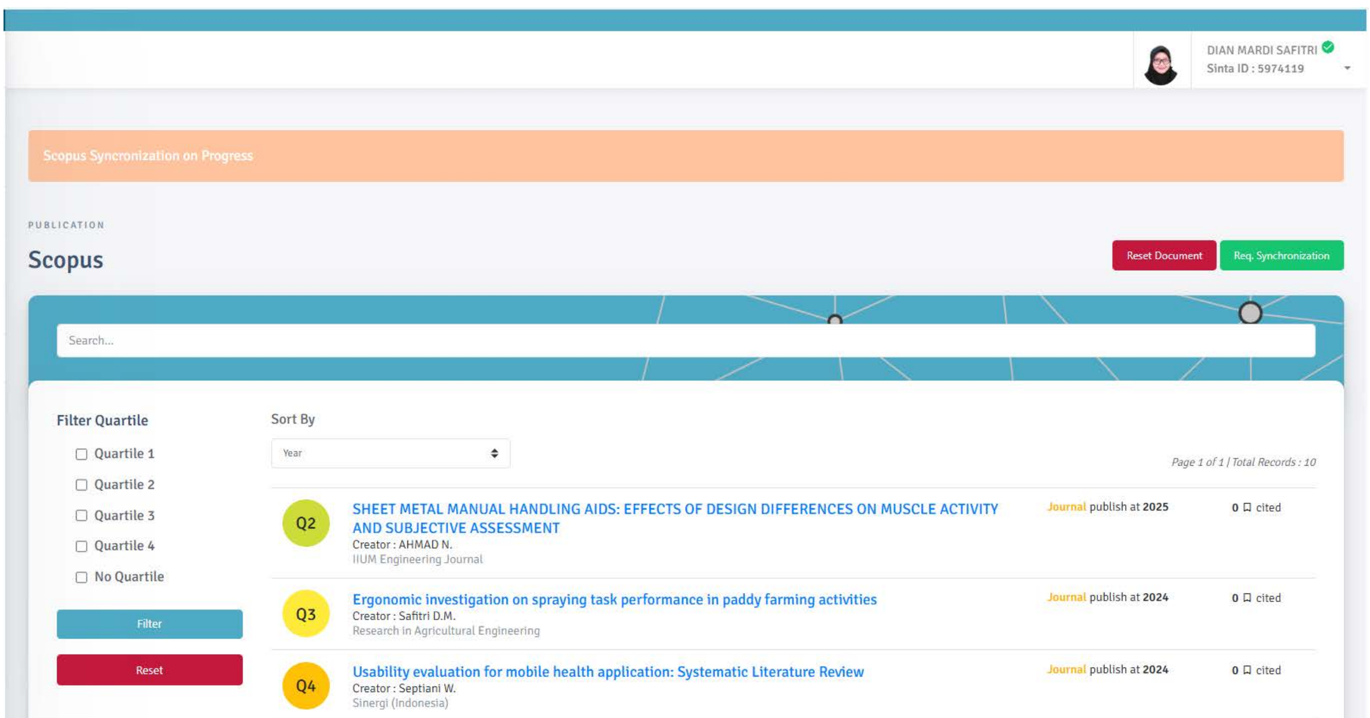

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Lemons are fruit products that grow well in Indonesia. Montaji Agrihorti is one of the lemon varieties found in Indonesia, a new variety developed by Balitjestro breeding. This lemon variety is seedless. In fact, lemons are harvested nearly all year-round. Equally important, evaluating the fruit's maturity level is crucial for determining the optimal harvest time. In this study, standardizing measurement on maturity level was conducted through Vis-NIR spectroscopy and machine learning models. In this case, non-destructive data from Vis-NIR spectroscopy were correlated with parameters related to fruit maturity and quality, such as soluble solid content...

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The display of the depth of operation on tractors' dashboards facilitates the operator in achieving precise operation. In this study, the depth of operation of a mounted implement was measured and digitally displayed on a tractor's dashboard. The change in depth of operation was sensed by measuring the rotation of the rocker arm of the tractor's hydraulic system. The measured angle of rotation was multiplied by a calibration factor to convert it into the actual depth of operation in centimetres. For the calibration factor, a geometrical analysis of the three-point linkage was carried out, and a mathematical relationship was established based...

DIAN MARDI SAFITRI - Ergonomic investigation on spraying task performance in paddy farming activities

by Dian Mardi Safitri

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Ergonomic investigation on spraying task performance in paddy farming activities

Dian Mardi Safitri[1,2]*, *Novia Rahmawati*[3], *Winnie Septiani*[1,2], *Nora Azmi*[1], *Azizah Nurul Hanifati*[1], *Ummi Noor Nazahiah binti Abdullah*[4], *Norashiken binti Othman*[4]

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Abstract: The commodity rice in Indonesia and the administration of rice fields are given particular focus by the government. Spraying activities are known to increase the risk of exposure to chemicals for farmers, resulting in a loss of working days for 3–7 days. It is necessary to carry out ergonomic interventions for spraying activities to make the activity safer for farmers. This research aims to identify the ergonomics and safety problems of spraying activities in rice field farming, to analyse and develop intervention parameters to solve issues in spraying activities, and to generate innovative design concepts to overcome spraying problems. Prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the functional requirements can be strong, moderate, weak, and zero (no ties). This relationship determines the technical importance of the rating. From the assessment of the relationship between the customer and the functional requirements, it can be seen which technical specifications should be prioritised for developing the product. An automated system is the technical specification that should be prioritised because it has the most significant weight on meeting the consumer needs.

Keywords: agriculture; human factors; musculoskeletal problems; risk; safety and health

The main types of jobs in the Indonesian population aged 15 and over are in the agriculture, forestry, and fisheries sectors, with 37 130,676 people or 28.33% of the population [Statistics Indonesia (BPS) 2024)]. The agricultural sector in Indonesia is very strategic because more than 70% of the primary income of the rural population comes from farming. The agricultural industry is vital and has the government's attention in order to improve the nation's economy and increase the productivity and welfare of farming families. However, rice farming activities in paddy fields pose a significant risk to one's occupational safety and health (Sudiajeng et al. 2024). Rice farmers face this risk (Walker-Bone and Palmer 2002) considering that rice farming in wet (irrigated) and dry (rainfed) rice fields in Indonesia is operated traditionally. Rice farming in other Southeast Asian Countries has almost the

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same characteristics as its management in Indonesia (Akbar et al. 2023). The countries want to improve the rice paddy farmers' performance because rice is the countries staple food. In Indonesia, the cultivation and management of rice paddies are a significant part of life and receive special attention and support from the government. The policy and concerns relate to the food security of the two countries. Rice field activities in both countries have the same stages, starting from the land preparation, seed nursery, nurseries, planting, maintenance (fertilising and spraying), and harvesting. However, the spraying activity, a crucial part of the maintenance stage, is known to cause a risk of exposure to chemicals for farmers, resulting in a loss of working days for 3–7 days. This is a significant concern that necessitates ergonomic interventions for spraying activities to make farming activities safer for farmers (Nawi et al. 2016). An automated spraying technology is the chosen type of intervention because farmers need a safer spraying tool to prevent the risks. The intervention reduces the loss of working days in the agricultural sector and increases the productivity and performance of farmers. The results of this study significantly improve the rice paddy farmers' quality of life, underscoring the importance of this research.

Agricultural activities, both traditional and automated, using tools can be an ergonomic hazard and pose a risk to farmers. Many studies on ergonomics risk factors in agriculture have been carried out. The most dominant risk is work-related musculoskeletal disorders (WMSDs) on part or all of the body (Zanatta et al. 2021). WMSDs can occur in the upper part of the body (Harith et al. 2021; Mohamaddan et al. 2021) and lower part of the body (Hota et al. 2020). The literature states that all agricultural activities, including land preparation, seeding, planting, and maintenance/spraying, can become an ergonomic hazard (Zanatta et al. 2021), harvesting (Houshyar and Kim 2018; Harith et al. 2021; Thota et al. 2022). Activities that use machines can also become an ergonomic hazard (Kociolek et al. 2018). The risk factors associated with using agricultural machinery are related to vibration or vibration (Thota et al. 2022). The effect of vibration from using these tools is also felt in all parts of the body. This vibration can be the cause of musculoskeletal disorders (MSDs). Risk factors associated with odd postures are also a hazard for musculoskeletal disorders in farmers (Franco et al. 2020). Other physical factors are repetitive movements and excessive exertion (Hota et al. 2020; Harith et al. 2021). The environment and agricultural land are also referred to as another ergonomic hazard, especially concerning thermal factors (López-Martínez et al. 2018), which cause heat stress on farmers. Various ergonomic interventions to improve the quality of work and quality of life of farmers have been proposed and designed, including designing more ergonomic agricultural tools to reduce the exposure to vibrations (Thota et al. 2022), automatic ladders to minimise the risk of shoulder injuries in tall crop harvesting (Thamsuwan and Johnson 2022), farmer work shift arrangements (Mohamaddan et al. 2021), the application of the time of the farming protocol (Hota et al. 2020), the design of gloves for harvesting (Chauhan et al. 2020), the design of cooling jackets to overcome thermal discomfort (Del Ferraro et al. 2021), etc. Ergonomic interventions to minimise risks to occupational health and safety can also be carried out at the organisational or farmer group level. An example is education for farmers regarding safe work postures (Lee et al. 2021; Caffaro et al. 2022). This is one of the potential efforts required to improve the safety climate at the organisational level (Kjestveit et al. 2021).

Technology is essential in controlling ergonomic hazards in agriculture to reduce the risk of heat stress due to extreme and dangerous natural conditions for farmers. One that can be pursued is to design a weather network station capable of collecting data on environmental parameters related to the workers' welfare (López-Martínez et al. 2018); robots can also help humans work in a better way (Vasconez et al. 2019). In the era of Agriculture 4.0, information technology also plays a crucial role in agriculture, and various kinds of intelligent farming designs can be used (Klerkx et al. 2019). In addition to physical hazards, agricultural activities also have psychological hazards. As with the activities and workload on the non-agricultural activities, physical and mental demands are always present. Farmers are also at risk of mental stress in traditional agricultural activities that depend on the season and rainfall. Therefore, a psychological approach must also be designed to minimise the ergonomic risks due to mental stress (Lee et al. 2021).

The spraying activity is recognised as having the change to increase the chemical exposure for farmers, resulting in a loss of working days for 3–7 days.

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It is necessary to carry out ergonomic interventions for spraying activities so that these activities can be carried out more safely for farmers. A drone technology is the chosen type of intervention because it is a safe spraying tool that can prevent the risk of poisoning hazards to farmers. With this intervention, it is hoped that the loss of working days in the agricultural sector will be minimised and the productivity and performance of the farmers will be increased. The results of this study are expected to improve the quality of life of rice paddy farmers. Therefore, this study aims to identify the safety ergonomics of spraying activities in rice field farming and develop intervention parameters to solve the problems related to the spraying activities.

MATERIAL AND METHODS

The sample and location selection consider the appropriateness and obtainability of the observed activities. The study sample and respondents in Indonesia are located in Pawidean Village, Jatibarang, Indramayu, Indonesia. This research involved 30 farmers from Pawidean Village and 4 Indramayu district agricultural service officers as the respondents. The study was undertaken from November 1st 2022 to August 31st 2023. This study consists of two phases to achieve the research objectives described in Figure 1. The Ergonomics Risk Assessment is a tool for analysing ergonomic risk in an activity. This tool examined the ergonomic risk factors that cause work-related musculoskeletal disorder problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist investigates the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is thought to be the cause of the farmers' mental burden. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity improves. Persona techniques are in-depth interview techniques with experts. This interview technique was conducted to complete the information and input data obtained from the field observations. Benchmarking is an approach for identifying the best practices in product design development and improvement activities. The brainstorming technique for product design compares the reference products with the plans resulting from the research, which was helpful in the design criticism by mapping the advantages and disadvantages of the reference products. The house of quality in the quality function deployment is a tool that can translate consumer desires into technical characteristics in design. Figure 1 displays the research methodology.

Phase 1: Problem identification and risk assessment. Ergonomics Risk Assessment (Chander and Cavatorta 2017; Zelik et al. 2022) analyses the

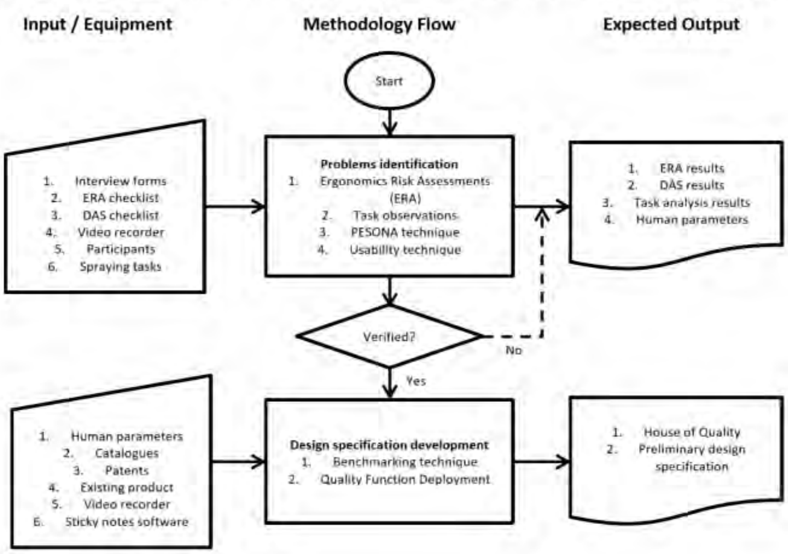

Figure 1. Research methodology

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ergonomic risk in an activity. This tool explored ergonomic risk factors that cause Work-related Muscle and Skeletal Disorders (WMSD) problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist (Bilgel and Bayram 2010) studied the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is claimed to be the cause of the mental burden on farmers. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity increases. Persona techniques are in-depth interview techniques with experts. The interview technique was conducted to complete the information and input the data obtained from the field observations.

Phase 2: Design specification development. A brainstorming technique for product design, comparing reference products with the plans from the research, was used for the design criticism, mapping the advantages and disadvantages of the reference products. Benchmarking is appropriate in product design development and improvement activities. Quality Function Deployment (QFD) (Finger and Lima-Junior 2022; Akao and Mazur 2003) is a tool that can translate consumer desires into technical characteristics in design.

RESULTS AND DISCUSSION

Work environment analysis. A lux meter measured the luminance level during the farmer's working time. The measurement results show that the average light level in the rice field area is 5 709 lux, with the highest light level being 6 057 lux. Noise is one of the environmental factors that can affect human work performance. During the spraying activity, it turned out that the noise level was classified as safe because it was below the hazard threshold. The sprayer farmers use in Pawidean Village does not cause any harmful noise. Like other parts of Indonesia, Pawidean Village is an area that gets quite a lot of sun exposure. At the time of the study, the UV Level Meter (Mobile version Lux Light Meter Pro, Canada) measures the UV exposure levels. At the time of observation, the average UV index measurement at the study site was level 3, or at a moderate level. The UV Index measurement was from 8.50 to 14.30 at the local time.

Farmers always consider the wind direction and speed in spraying activities to determine the best and safest spraying time. During observation, the wind blew at 9.5 km·h^{-1} from west to east. The right time for spraying rice plants is in the morning, around 7:00 to 9:00 p.m., or in the afternoon after *Ashar* time, around 3:30 to 5:00 p.m. At that time, predicting the wind direction and speed was easier. In addition, at that time, the stomata of the leaves were wide open because the temperature was not too high. In high-temperature environments, leaf stomata close, and spraying is not effective.

Spraying activity analysis. The following in Figure 2 shows the position of the farmer's body when the spraying activity is carried out. The picture is taken

Figure 2. Body position spraying activity from the left side

Table 1 Work environment hazard analysis

Factor*	Measuring tool	Result	Hazard risk level measurement
Lighting	lux meter	the average level is 5 709 lux, with the highest level of illumination at 6 057 lux	natural lighting, safe
Noise	sound level meter	average 47.6 dBA during the spraying activity	low
Temperature	thermometer	average 30 °C	safe
UV Exposure	UV level meter	level 3	moderate
Wind	anemometer	the speed is 9.5 km·h^{-1} from West to East	

*Result of hazard risk level measurement

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from the farmer's left side to indicate the role of the farmer's arm—the farmer's right hand controls the sprayer, which is about 1–1.5 m long. The atomiser is a tube carried on the back with a shoulder strap.

There are three types of spray equipment currently used by farmers. To make it easier to compare their specifications, they are called types A, B, and C. Table 2 shows a comparison of the specifications of the spraying equipment. Figures 3 and 4 illustrate the diverse types of hand-pump sprayers utilised in Pawidean Village, showcasing their different designs and functionalities as they adapt to the local agricultural practices.

In analysing the use of the current spraying kit, some challenges must be overcome related to the detailed understanding of the technical specifications of the spraying equipment. Data were collected by investigating the product specifications from the manufacturers' and sellers' websites. The respondents did not care about the detailed technical specifications of the sprayer because the considerations in choosing a sprayer were based on the price, tank capacity, and power used, and whether it was necessary to use a battery or a manual pump.

The respondents' education backgrounds were elementary and junior high school. This is the general profile of traditional farmers in Indonesia who have a low educational background. Besides that, the farmers in Pawidean village are, on average,

Table 2 Comparison of the specifications of spraying equipment currently used

Fators	Spraying equipment		
	type A	type B	type C
Capacity	16 L	20 L	16, 20, 17 L
Power	rechargeable battery 12V – 8 Ah	mixed gasoline and oil 2Stroke (25 : 1)	power rechargeable battery 12V – 8Ah mixed gasoline and oil 2Tak (25:1) Human
Price	IDR 995,000	IDR 1,699,900	price IDR 995,000 IDR 1,699,900 IDR 540,000
Carrying technique	carried	carried	moving procedure: carried
Tube materials	polypropylene (PP)	tank baffle design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs.	polypropylene (PP) tube material tank baffle design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs. stainless steel
Pump models	diaphragm pump with speed control		
Pump pressure	1–4 kg·cm^{-2}	5–25 (kg·f cm^{-2})	pump model diaphragm pump with speed control
Spray lances	telescopic spray lances		pump pressure 1–4 kg·cm^{-2}, 5–25 (kg·cm^{-2})
Nozzles	T-jets; 1&4 holes hollow cones		spray lances telescopic spray lances.
Application	Herbicide, liquid insecticide	pest medicine, liquid fertilisation	T-jet nozzles; – & 4-hole hollow cones
Dimensions	l – × w – × h – 395 × 220 × 151 mm	40 cm × 36 cm × 70 cm	Application Herbicide, Liquid Insecticide Pest Medicine, Disinfectant Liquid Fertiliser, Pest Medicine, Liquid Fertiliser
Value Added/ Advantage	16 L	Equipped with: Smart cable clip = a clip designed to tidy up the cables on the machine so there is no cable twist and protect the cord (Clips can be moved). Deep strainer basket = filtering tool/basket designed deeper so that it is faster for filtering and filling into the tank	Dimensions: length = 395 mm width = 220 mm height = 151 m

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Figure 3. Hand-pumped manual sprayer

the elderly and have been farmers for tens of years. In this research, it was identified that they have been farming for more than ten years.

There were problems regarding the regeneration of the farming profession in Indonesia, where the children of farmers tend not to become farmers like their parents because the traditional farming system in Indonesia is difficult and expensive (Sari et al. 2024) managing the trade-offs between economic and ecological targets. Serious games can be abstract and generic, or more complex and specific. They can be used to raise awareness, increase shared understanding of options and risks, and/or commitment to common goals.\nOBJECTIVE\nWe here aim to clarify design principles applied in the FORCES game (Farmer Options and its Risk in Complex Ecological-Social systems). Even though Indonesia's agricultural challenges are enormous, farmers' children were encouraged to get a higher education and work in the industry. With an ageing farmer demographic, adaptation of agricultural technologies becomes difficult. In spraying activities, the local Department of Agriculture has socialised the use of agricultural drones to assist rice plant maintenance activities. Still, there are obstacles to the acceptance of this technology. The following is a list of reasons why the survey found adaptation to the use of agricultural technology in Indramayu. First, using drones is a hassle because farmers cannot do it whenever they feel it is necessary. Secondly, farmers think that spraying with drones causes spraying drugs to be more wasteful because they do not target plants appropriately. A spraying distance that is too far from the plant causes the spray drug not to be absorbed optimally. Finally, spraying with drones is impractical for pest control because it does not reach the stems and roots. This is caused by the position of the spray from above, while the pests are often in the stems and roots of plants.

Figure 4. Variations of spray tools used by pawidean village farmers

Usability analysis of the spray equipment currently used. A questionnaire was developed to evaluate the use of the agricultural spraying equipment currently used. This questionnaire was filled in by three farmers who routinely sprayed. Two respondents use a battery sprayer daily, while one uses a manual pump sprayer. Both were asked for their opinion to assess the usefulness of the sprayer. An ease of use analysis is needed to provide an overview of the interaction between the farmers and the spray equipment. A product interacts more closely with humans if the level of usability is good. The current spray equipment seems to have good usability and ease of use. This convenience seems to satisfy the users, both from the first time of service to routine use. 66.7% of respondents

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stated that the sprayer they are using now helps them spray the targeted paddy fields. The remaining 33.3% have a neutral opinion, which can be interpreted to mean that the current sprayer does not always help. All the respondents gave neutral answers to whether the current sprayer helps them to spray daily. This means that spraying is not undertaken every day.

100% of respondents stated that the sprayer, which is now helpful in spraying their rice fields, can be easily controlled by farmers for all rice fields and makes spraying activities easier. In the statement that the spray equipment can save working time, 66.7% of respondents disagreed, and 33.3% agreed. The current sprayer may not be able to meet the expected uptime-saving requirements. 33.3% of respondents stated that their spray equipment was not able to meet their needs.

Ergonomic risk analysis. The ergonomic risks referred to in this study are the risks of work-related musculoskeletal disorders suffered by farmers. Data regarding ergonomic risk were recorded for six respondents, all active farmers in Pawidean village. The respondents, apart from spraying, also carried out other agricultural tasks. The farmers' working hours vary, depending on their preferences and habits in carrying out activities. 100% of respondents work with their right hand, and their work experience is at least five years. Mental fatigue mainly occurs infrequently, and physical fatigue mostly occurs frequently. In the last year, 100% have felt pain/pain/discomfort related to their agricultural activities.

Farmer's mental load analysis. The mental load is identified and measured using the 42 item depression anxiety and stress scale (DASS-42) questionnaire. Structured interviews and discussions were used. The surveyor obtained information about what the respondents felt related to their work in this observation – in this case, related to the agricultural activity. Forty-two symptoms of exposure to mental overload were identified and confirmed to the respondent, whether they had been experienced or not, and how often these symptoms occurred. The results of measuring the depression level of farmers in Pawidean village show that the respondent's answer mode shows a scale of 0–1. This indicates that there are no indications of depression in farmers. Measuring the Pawidean village farmers' anxiety levels shows a scale of 0–3. This suggests that farmers feel no indication of anxiety. Measurement of the stress level of Pawidean village farmers shows a scale of 0–1. This indicates that there are no indications of stress on the farmers.

Depression. One symptom indicator is feeling no longer strong enough to carry out activities, with a value of 1 (sometimes). If related to the results of the interviews with the farmers, most farmers are over 50 years old and have concerns that no one continues their work as farmers.

Anxiety. Some measurable anxiety symptoms are dry mouth, fatigue, sweating, and behaviour for no noticeable reason. The observed farmer activity was spraying once every ten days. Based on the results of the interviews with the farmers, the triggers for their anxiety are concerns about the crop/harvest and fatigue in spraying with a large amount of land. The sprayers owned by the farmers are less ergonomic.

Stress. Anxiety arises primarily due to the harvest.

Agricultural spraying equipment benchmarking. Spray equipment with drone technology in Indonesia has not been widely implemented because most rice farms use traditional labour-intensive systems. Drone technologies for agriculture have many uses, including plant health monitoring, plant-

Table 3 Problems of using drone spraying

No	Constraint	Source
1	Farmers are still not aware of the role of drones in helping their work	Simatupang et al. (2021), observation
2	Prices are still relatively expensive	Simatupang et al. (2021), observation
3	Difficult drone maintenance	Simatupang et al. (2021)
4	Not a practitioner because they must use the services of a third-party	observation
5	Availability of drone rental services is limited or non-existent	observation
6	Ownership of drones by farmers is not yet possible	observation
7	There must be training for drone operation	observation
8	The pesticide spraying was not on target, and it was wasting	survey results
9	It is not easy to spray the parts of the plant that are close to the roots.	survey results

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Table 4 Identification of the needs for the agricultural sprayer

Current spraying constraint	Farmers' expectations of the spraying equipment	Identification of needs
Heavy spray equipment, resulting in body aches	Want a lighter sprayer	Light sprayer
The wind is often challenging to predict the direction and speed	Want a tool that can read the direction and speed of the wind when spraying	The sprayer can determine the wind direction and wind speed
Often drunk due to drug spray poisoning	Want a safer sprayer	Spray equipment does not interfere with health
Plant	Want a spray tool that can reach up to	Spray equipment can access parts of the plant that are difficult to reach
Pests are often on the stems and near the roots	shadows and near roots	Spray equipment can save the use of pesticides
The prices are high because sprays are destroyed in the wind	Want a spray tool that is more efficient and right on target to be more efficient in using the poison spray?	The sprayer is easy to use
Not all farmers are skilled at spraying	Want a tool that is easier to use so everyone can do the spraying activity?	Long lasting sprayer

ing and nursery care, the treatment and spraying of plants, and pollination. Unfortunately, the adaptation of drone technologies to agriculture has encountered many obstacles. The reason is that drone spraying technologies still have many limitations. The use of drones is very dependent on weather conditions. Spraying using a drone must be undertaken when the weather is sunny and the wind speed is low. Identification of the difficulties in using drone spraying was carried out through literature studies and observations. The results are shown in Table 3.

In Indonesia, drones are used more on oil palm, acacia, and tea plantations. In addition to spraying, the farmers operate drones to map the plantation land. Modern farmers use spray drones for liquid fertiliser applications and pest control. The type of pest also determines the type of poison used. Rats, insects, and caterpillars are the most common pests. A discussion with an agricultural drone supplier validates the problems surrounding using drones for agriculture. Spraying with drones is often not on target for the types of pests hiding under the leaves. Therefore, the spraying intervention must concern not only the design of the nozzle, but also the dose and type of poison used. The opening of the spraying nozzle must be adjustable so that the strength and dosage of the spray drug are also suitable for plant problems. The role of farmer cooperatives could solve the problem of financing and renting drones for agriculture in Indonesia. Individual ownership of paddy fields is generally an obstacle to adaptation to the use of drones due to the high cost. Table 4 identifies the need for agricultural sprayers.

Consumer needs are the basis for determining the functional needs of agricultural sprayers. The consumer needs the data in Table 4, which is then translated into quality function deployment (QFD). QFD is a design planning process driven by customer requirements (Goetsch and Davis 2016). The QFD stages are presented in Figure 5. The following analysis of the stages produces twelve functional requirements for agrarian spray equipment: dimension, materials, weight, automated system, spray speed, spraying height, number of rotors, tank volume, area efficiency per flight, flight radius, droplet size, and nozzle quantity.

The prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the operational requirements is vital, moderate, weak, and zero (no ties). This relationship determines the technical importance rating. From assessing the relationship between the customer and the functional requirements, we detect which technical specifications are the priority in order to develop the product. An automated system is the technical specification that is the priority because it has the most significant weight on meeting the consumer needs. The following sequence is droplet size and nozzle quantity. The benchmarking analysis of the competitor products determines the

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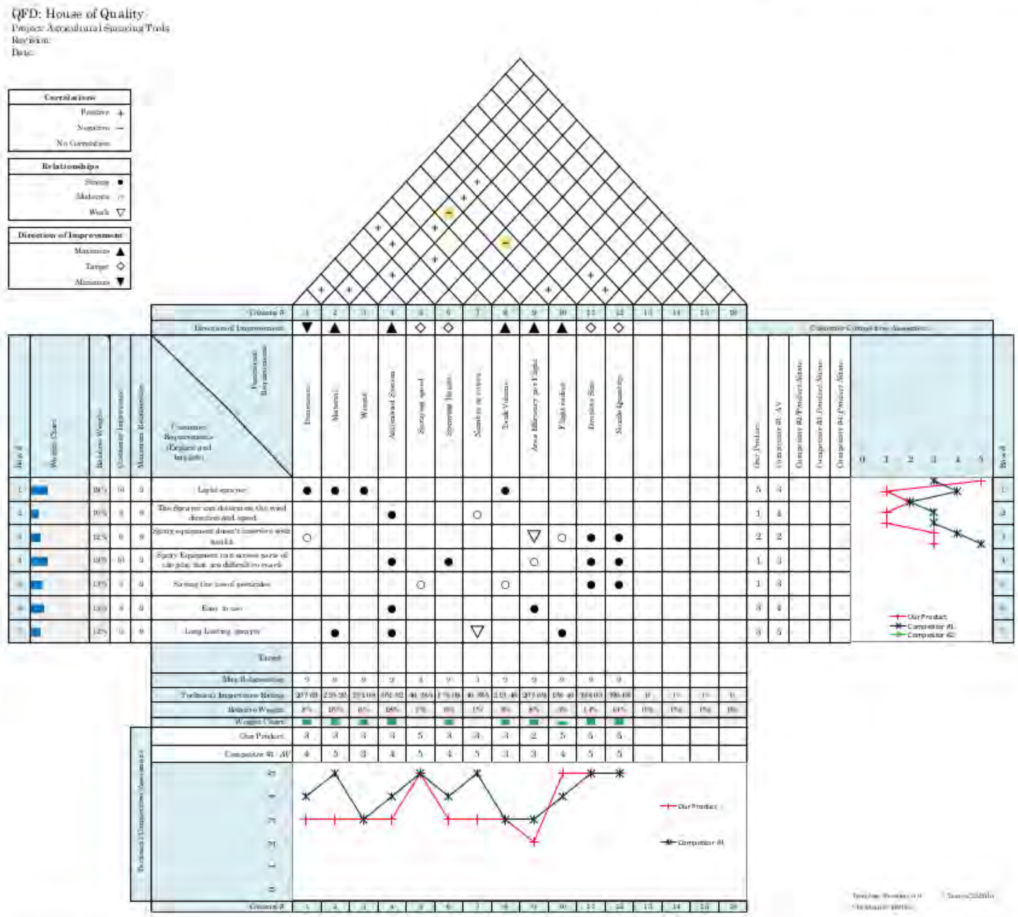

Figure 5. House of quality

strengths and weaknesses of the product. Consumers compare the product with competitors' products when it has entered the market. Product designers are required to anticipate this competition.

The benchmarking analysis of competitor products determines the strengths and weaknesses of the product being developed. Consumers compare the moulded product with the competitors' products when it has entered the market. Product designers are required to anticipate this competition.

CONCLUSION

An ergonomic risk is found in maintaining rice plants, specifically the risk of musculoskeletal disorders. The agricultural work environment exposes farmers to hazards, especially related to the light, wind, and UV radiation. There was no excessive mental burden on the agricultural work despite the many difficulties faced by the farmers. The sprayer currently used by the farmers is a sprayer that is carried on the shoulders and back, operated by battery power and a manual pump. In general, the farmers are satisfied with the use of this sprayer. However, there is still an expectation for the availability of alternative spraying equipment that is safer, more efficient, and easier to use. Mapping the need for agricultural spraying equipment using a house of quality shows that farmers consider spray equipment that is light and can reach the most difficult parts of the rice plant. These two needs can be seen from the results of the weighting of the needs, ob-

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taining the highest weight, namely 19%. The technical specifications of an ergonomic sprayer to answer this need are the number of nozzles on the sprayer and the size of the produced droplets. Each of these specifications has a weight of 14%.

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Kepada: "Ing. Gabriela Uhlířová" <rae@cazv.cz>

Dear **Ing. Gabriela Uhlířová,**

I'm sorry for the late response; it was due to the year-end holiday. I have response the final proofread on the web journal system.
Here I enclosed the revised proofsheet pdf file.
I have done all the revision required.
Based on our University policies and rules, we are required to use the name written in Indonesian: Universitas Trisakti as an official identity.
IPB is not an abbreviation, it's the name of the University.
Citation and keyword are revised.
The Ergonomics Risk Assessment is not a software, it's the name of our research framework.
The reference sentece for figure 3 and 4 is written in page 5.
The references section are revised.

Thank you, and happy new year

Warm Regards,

Dr. Dian Mardi Safitri
Industrial Engineering Department
Faculty of Industrial Engineering
Universitas Trisakti, Jakarta, Indonesia
+62 81905432200
Pusat Kajian Ergonomi, Kesehatan dan Keselamatan Kerja (ErgoK3) – Improving Quality of Life (trisakti.ac.id)

[Kutipan teks disembunyikan]

80-2024-RAE_proofsheet 12-31-24.pdf
968K

UNIVERSITAS TRISAKTI

Dian Mardi Safitri <dianm@trisakti.ac.id>

Automatická odpověď: Fw: 80/2023-RAE Ergonomic Investigation on Spraying... Proofsheet

1 pesan

Ing. Gabriela Uhlířová <rae@cazv.cz> 31 Desember 2024 pukul 22.37
Kepada: Dian Mardi Safitri <dianm@trisakti.ac.id>

Dear Madam/Sir,

Thank you for your email. I am currently out of the office and unavailable until December 31. I will respond to your email as soon as possible upon my return.
Yours sincerely,

Ing. Gabriela Uhlířová
Executive Editor (Research in Agricultural Engineering)

Czech Academy of Agricultural Sciences
Slezská 100/7
120 00 Prague 2
Czech Republic
Tel.: + 420 227 010 471
rae@cazv.cz
www.agriculturejournals.cz

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art. no. 80/2023-RAE: Deadline for submitting revised manuscript is near

1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz> 1 Oktober 2024 pukul 06.31
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

Dear Dian Mardi Safitri,

The deadline for submitting your revised manuscript version is near

Control robot of the review management system of the journal Research in Agricultural Engineering is informing you that the deadline for handing over the revised version of the manuscript "Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities" is approaching.

To submit the revised manuscript «CLICK HERE».

E-mail was generated by the system automatically.

Research in Agricultural Engineering

Czech Academy of Agricultural Sciences
Slezská 7
120 00 Prague 2
Czech Republic

http://rae.agriculturejournals.cz

- Message sent: *October 1, 2024 01:31:04*
- Deliver to: *Dian Mardi Safitri*

Sent by Actavia system on Research in Agricultural Engineering website.

UNIVERSITAS TRISAKTI

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art. no. 80/2023-RAE: Manuscript accepted, closed

1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz> 18 Oktober 2024 pukul 18.23
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

Dear author,

We would like to inform you about the statement of the Editorial Board: Manuscript accepted

We would like to inform you that the Editorial Board of the Research in Agricultural Engineering has accepted the manuscript "Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities".

Note:

Dear authors,
It is my pleasure to inform you that your contribution was accepted for publication in Research in Agricultural Engineering scientific journal and will appear in one of the next issues.
Thank you for the opportunity to assess your contribution and we look forward to further possible cooperation.
Yours sincerely,
Editorial office

E-mail was generated by the system automatically.

The review cycle of this manuscript has been closed. The Editorial Board thanks you for your cooperation.

Research in Agricultural Engineering

Czech Academy of Agricultural Sciences
Slezská 7
120 00 Prague 2
Czech Republic

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UNIVERSITAS TRISAKTI

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art. no. 80/2023-RAE: Proof-reading of article
1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz> 29 Desember 2024 pukul 18.13
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

Dear Dian Mardi Safitri,

We are sending you the proof-sheet

The Editorial Board of the Research in Agricultural Engineering is sending you the final version of the article "Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities" for proof-reading.

Please, read the text of the manuscript carefully and make sure to respond to all the comments that you will find in the text (usually marked by a yellow colour) or requested changes (for example: better quality figures, missing explanations etc.).

Please, comment on the proof-sheet if necessary with the Adobe Acrobat comment feature (bubbles) and upload the corrected proof-sheet file to the editorial system under the same ID within 48 hours.

To see the manuscript status «CLICK HERE».

Thank you.

Note:

Please send us back your revised manuscript as soon as possible (within 24 hours at the latest). The manuscript will then be published.

E-mail was generated by the system automatically.

Enclosed you will find the reviews.

Research in Agricultural Engineering

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- Message sent: *December 29, 2024 12:13:13*
- Deliver to: *Dian Mardi Safitri*

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Proofreading art. 31993.pdf
4816K

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art. no. 80/2023-RAE: Review of manuscript
1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz>
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

30 September 2024 pukul 22.09

Dear Dian Mardi Safitri,

Review of manuscript

Conclusion: manuscript has been accepted

The Editorial Board of Research in Agricultural Engineering is sending you the review of manuscript "Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities"

To see the manuscript status «CLICK HERE».

Note:

After incorporating the requirements of reviewer 2, your article will be accepted. Please edit, thank you.

For correction, please, use the MS Word Track Changes function. Please, submit the corrected manuscript and also the accompanying letter in anonymized form. See the Instructions for Authors.

We kindly ask you to resubmit the corrected manuscript under the same identification number.

In the accompanying letter, please respond to all suggestions of reviewers and inform us whether you accepted their suggestions or not and what revisions you made in the original text of the paper according to these suggestions.

Please, see the file attached for the reviewers' comments.

Please, revise the paper within the deadline given below. In case you need more time, please inform the Executive Editor of the journal.

E-mail was generated by the system automatically.

Enclosed you will find the reviews.

Research in Agricultural Engineering

Czech Academy of Agricultural Sciences
Slezská 7

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Czech Republic

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- Message sent: *September 30, 2024 17:09:40*
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Reviews art. 31993, ver. 5.pdf
128K

UNIVERSITAS TRISAKTI

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art.no. 80/2023-RAE: Notice of DOI assignment

1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz> 1 Januari 2025 pukul 00.33
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

The DOI of Your manuscript has been assigned...

Dear Madam/Sir,

Your manuscript has been published in Res. Agr. Eng., 2024, 70(4).

Title: **Ergonomic investigation on spraying task performance in paddy farming activities**

Article website link: https://doi.org/10.17221/80/2023-RAE

Article doi: 10.17221/80/2023-RAE

Please promote your article by sharing the link to your article with your colleagues and friends.

You can share it by email or social networks (Facebook, Twitter, LinkedIn, ResearchGate etc.)

Yours sincerely,

Ing. Gabriela Uhlirova RAE

Research in Agricultural Engineering

Czech Academy of Agricultural Sciences
Slezská 7
120 00 Prague 2
Czech Republic

http://rae.agriculturejournals.cz

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UNIVERSITAS TRISAKTI

Dian Mardi Safitri <dianm@trisakti.ac.id>

Research in Agricultural Engineering - art.no. 80/2023-RAE: Your manuscript was delivered
1 pesan

Ing. Gabriela Uhlirova RAE <rae@cazv.cz> 1 Oktober 2024 pukul 13.30
Balas Ke: rae@cazv.cz
Kepada: dianm@trisakti.ac.id

Dear Dian Mardi Safitri,

This is information on the delivery of an actualized manuscript version.

The Editorial Board of Research in Agricultural Engineering thanks you for sending a new version of manuscript "Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities".

To see the manuscript status «CLICK HERE».

E-mail was generated by the system automatically. You will be informed on further development.

Research in Agricultural Engineering

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80/2023-RAE Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities

Reviews ver. 1

Review no. 1: Publish after major revisions and a second review

The manuscript is within the scope of the Journal. The English language is satisfactory, and readers will understand the information presented. The authors presented information on ergonomics and safety problems of spraying activities in rice field farming among other objectives. To maintain the impact and quality of the Journal, it is important the Authors revise their work according to the following comments:

General Comments
- The manuscript is not within scientific merit. The information presented is not properly and scientifically organized.
- Avoid numberings of information in the text/manuscript. Organize information in a form of paragraphs or meaningful sentences for readers understanding.
- The format/style of Tables and references should follow the Journal's Instructions for Authors.
- Figures should be compressed into a single figure using a, b, c and d form of illustration (eg Figures 6, 7 and 8 should be organized into a single Figure using a, b and c formats).
- The use of 'will analyze or will cause' should be placed in appropriate tenses. Note that the study is done, and the results/information should be a reported speech and not a future work.
- Statistical interpretation of the results is missing. The design of the study was not based on statistical design of experiments. What is the statistical significance of the results presented?
- The methods and results should be described appropriately and discussed scientifically.
- Follow the Journal's Instructions for Authors and organize your work appropriately and scientifically to meet scientific standard/merit.

Specific Comments
1. Page 1: Line 19: Delete 'In the following sequence are Droplets Size and Nozzle quantity.
2. The abstract should be organized to provide the scientific findings of the study.
3. Introduction: The Introduction is poorly organized. Organize the Introduction into appropriate paragraphs for clarity.
- Avoid numberings in the Introduction (Page 2: Lines 2-8, should be deleted or arrange a sentence form).
- Page 4: Lines 7-10, the objectives of the study should be placed at the end of the Introduction.
- Page 4: Lines 12-15, the information should be placed in appropriately in the Materials and Methods section.
4. Materials and Methods: Page 4: Line 18; four phases as indicated but only two phases (Phase 1 and Phase 2) were mentioned on Page 5 - Line 4 and Line 17.
5. Tables and Figures numberings are not in ascending order. No Table 1, No Figures 2-5
6. In Table 2; why the results for UV Exposure is 3?
7. Results and Discussion: Avoid numberings in the text. Check the comments given in the 'General Comments' above.
8. Figure 1 is mentioned on Page 5 - Line 2 and Page 17 - Line 2.
9. Conclusion: The conclusion should provide the specific findings of the study based on statistical interpretation, not just experimental data.
10. References: Should follow the Journal's Instructions for Authors.
- Refer to the Journal's Instructions for Authors, and check the format/style of 'in-text citations' and list of references format.

Does the subject matter fit the scope of the journal?	*no*
Originality	*good*
Technical quality	*fair*
Clarity of presentation	*fair*
Importance to field	*good*
Language quality	*good*
Citations	*good*
Conciseness	*good*
Completeness	*good*
International relevance	*good*
Scientific merit	*fair*
Article type	*Original Paper*
New knowledge	*present*
Methodology	*not suitable*
Interpretation of results	*minor deficiencies*

Review no. 2: Publish after minor revisions

Finding and choosing some correct technical terms will improve the qualty of the paper

Does the subject matter fit the scope of the journal?	*yes*
Originality	*good*
Technical quality	*fair*
Clarity of presentation	*good*
Importance to field	*good*
Language quality	*fair*
Citations	*good*
Conciseness	*poor*
Completeness	*good*
International relevance	*good*
Scientific merit	*good*
Article type	*Original Paper*
New knowledge	*present*
Methodology	*suitable*
Interpretation of results	*minor deficiencies*

Editor notes:

Citations in the text of the manuscript must be written as normal text, not in the equation editor as it is now. Edit it throughout the manuscript. Carefully check the guidelines for authors, such as unit writing style, you are writing it wrong. Units should be written with a semicolon, not a slash (alt0183)

In the references list, all references must be written according to instuction for authors (you can check it here: Instructions for authors - DOWNLOAD HERE)
An example:
Caffaro F., Roccato M., de Paolis G., Micheletti Cremasco M., Cavallo E. (2022): Promoting farming sustainability:

The effects of age, training, history of accidents and social-psychological variables on the adoption of on-farm safety behaviors. Journal of Safety Research, 80: 371–379.

It is necessary to attach a proof of proofreading of the English language

CZECH ACADEMY OF AGRICULTURAL SCIENCES

80/2023-RAE Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities

Reviews ver. 3

Review no. 1: Publish after major revisions and a second review

The revised manuscript requires further revision to meet scientific merit according to the following comments:

1. Introduction:
-Provide references to support the information presented in Lines 22-45 (Page 1) and Page 2: Lines 1-3.
-Organize the Introduction into three or four paragraphs.

2. Materials and Methods
-Provide a better description for Phases 1 and 2 on Page 4 - Lines 4 and 17.

3. Results and Discussion
- Transfer Tables 1-4, and Figures 2-4 to Materials and Methods.
- What does A, B and C stand for in Table 2? Provide the full meaning or better description.
- Provide the statistical interpretation of the results obtained and discuss them appropriately.
- Provide references to support the results discussed.
- Avoid the repetitions of the methodology descriptions in the Results and Discussion.
- Why is Figure 5 not mentioned in the results and discussion? - what is the purpose of Figure 5?

Other comments
- Please, read the Journal's Instructions for Authors to make sure the manuscript is revised accordingly.
- References should be checked with the Journal's Instructions for Authors. Ensure to provide the page and volume numbers of the Journal's Articles or cited references.
- Ensure that 'in-text citations' conform to the Journal's Instructions for Authors.

Review no. 2: Publish without change

The paper should be be appropriate to be published. Best regards

Editor notes:

Please carefully check the instruction for authors. Check how to writte the units, etc.

80/2023-RAE Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities

Reviews ver. 4

Review no. 1: Publish after major revisions and a second review

The revised version of the manuscript does not show the changes made according to the comments raised.
Please, highlight the changes made in the revised version of the manuscript.

The revised manuscript requires further revision to meet scientific merit according to the following comments:

1. Introduction:
-Provide references to support the information presented in Lines 22-45 (Page 1) and Page 2: Lines 1-3.
-Organize the Introduction into three or four paragraphs.

2. Materials and Methods
-Provide a better description for Phases 1 and 2 on Page 4 - Lines 4 and 17.

3. Results and Discussion
- Transfer Tables 1-4, and Figures 2-4 to Materials and Methods.
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Other comments
- Please, read the Journal's Instructions for Authors to make sure the manuscript is revised accordingly.
- References should be checked with the Journal's Instructions for Authors. Ensure to provide the page and volume numbers of the Journal's Articles or cited references.
- Ensure that 'in-text citations' conform to the Journal's Instructions for Authors.

Review no. 2: Publish after minor revisions

I found that the research that is written in this paper was carried out in West Java Indonesia, and not including other country. So mentioned Malaysia in abstract and in introduction means the writter treating other countries outside Indonesia who their farmers practising spraying technology also unequaly, let say the phillippines and/or Thailand, for example. So i suggest to cut information about Malaysia information in the abstract and in the introductory parts; except if the writter want to consider their results with Malaysia in the discussion section.

Best Regards,
reviewer.

Editor notes:

Please, read the Journal's Instructions for Authors to make sure the manuscript is revised accordingly! https://rae.agriculturejournals.cz/artkey/inf-990000-3400_Instructions-for-authors-RAE.php

In the revised version, the changes made must be clearly visible in order for the reviewers to assess the new version.

CZECH ACADEMY OF AGRICULTURAL SCIENCES

80/2023-RAE Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities

Reviews ver. 5

Review no. 1: Publish without change

The manuscript has undergone a series of revisions. The current form is suitable for publication. Therefore, I recommend accept in its present form for further processing and subsequent publication. However, if the manuscript is accepted by the Editor, then during the proofreading stage, the format of the 'in-text' citations should correspond to the Journal's guidelines.

Review no. 2: Publish after minor revisions

It would be consistent if information about Malaysia in the abstract is removed, to change into, let say, "South-East Asian Paddy Fields Farmers"; or just "Indonesian rice farmers", except you give an argument of why Malaysia is so special in your work and or have implication in your experiments.

CZECH ACADEMY OF AGRICULTURAL SCIENCES

80/2023-RAE Ergonomic Investigation on Spraying Task Performance in Paddy Farming Activities

Reviews ver. 1

Review no. 1: Publish after major revisions and a second review

The manuscript is within the scope of the Journal. The English language is satisfactory, and readers will understand the information presented. The authors presented information on ergonomics and safety problems of spraying activities in rice field farming among other objectives. To maintain the impact and quality of the Journal, it is important the Authors revise their work according to the following comments:

General Comments
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- Avoid numberings of information in the text/manuscript. Organize information in a form of paragraphs or meaningful sentences for readers understanding.
- The format/style of Tables and references should follow the Journal's Instructions for Authors.
- Figures should be compressed into a single figure using a, b, c and d form of illustration (eg Figures 6, 7 and 8 should be organized into a single Figure using a, b and c formats).
- The use of 'will analyze or will cause' should be placed in appropriate tenses. Note that the study is done, and the results/information should be a reported speech and not a future work.
- Statistical interpretation of the results is missing. The design of the study was not based on statistical design of experiments. What is the statistical significance of the results presented?
- The methods and results should be described appropriately and discussed scientifically.
- Follow the Journal's Instructions for Authors and organize your work appropriately and scientifically to meet scientific standard/merit.

Specific Comments
1. Page 1: Line 19: Delete 'In the following sequence are Droplets Size and Nozzle quantity.
2. The abstract should be organized to provide the scientific findings of the study.
3. Introduction: The Introduction is poorly organized. Organize the Introduction into appropriate paragraphs for clarity.
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- Page 4: Lines 7-10, the objectives of the study should be placed at the end of the Introduction.
- Page 4: Lines 12-15, the information should be placed in appropriately in the Materials and Methods section.
4. Materials and Methods: Page 4: Line 18; four phases as indicated but only two phases (Phase 1 and Phase 2) were mentioned on Page 5 - Line 4 and Line 17.
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6. In Table 2; why the results for UV Exposure is 3?
7. Results and Discussion: Avoid numberings in the text. Check the comments given in the 'General Comments' above.
8. Figure 1 is mentioned on Page 5 - Line 2 and Page 17 - Line 2.
9. Conclusion: The conclusion should provide the specific findings of the study based on statistical interpretation, not just experimental data.
10. References: Should follow the Journal's Instructions for Authors.
- Refer to the Journal's Instructions for Authors, and check the format/style of 'in-text citations' and list of references format.

Does the subject matter fit the scope of the journal?	*no*
Originality	*good*
Technical quality	*fair*
Clarity of presentation	*fair*
Importance to field	*good*
Language quality	*good*
Citations	*good*
Conciseness	*good*
Completeness	*good*
International relevance	*good*
Scientific merit	*fair*
Article type	*Original Paper*
New knowledge	*present*
Methodology	*not suitable*
Interpretation of results	*minor deficiencies*

Review no. 2: Publish after minor revisions

Finding and choosing some correct technical terms will improve the qualty of the paper

Does the subject matter fit the scope of the journal?	*yes*
Originality	*good*
Technical quality	*fair*
Clarity of presentation	*good*
Importance to field	*good*
Language quality	*fair*
Citations	*good*
Conciseness	*poor*
Completeness	*good*
International relevance	*good*
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The effects of age, training, history of accidents and social-psychological variables on the adoption of on-farm safety behaviors. Journal of Safety Research, 80: 371–379.

It is necessary to attach a proof of proofreading of the English language

https://doi.org/10.17221/80/2023-RAE

Ergonomic investigation on spraying task performance in paddy farming activities

Dian Mardi Safitri[1,2], Novia Rahmawati[3], Winnie Septiani[1,2], Nora Azmi[1], Azizah Nurul Hanifati[1], Ummi Noor Nazahiah binti Abdullah[4], Norashiken binti Othman[4]*

[1]*Industrial Engineering Department, Faculty of Industrial Technology, Universitas Trisakti, Jakarta, Indonesia*
[2]*Center for The Study of Ergonomics, Work Health, and Safety, Universitas Trisakti, Jakarta, Indonesia*
[3]*Vocational School, IPB University, Bogor, Indonesia*
[4]*Faculty of Engineering and Mechanical Technology, Universiti Malaysia Perlis, Malaysia*

Corresponding author: dianm@trisakti.ac.id

Citation: Safitri D.M., Rahmawati N., Septiani W., Azmi N., Hanifati A.N., Abdullah U.N.N.B., Othman N.B. (2024): Ergonomic investigation on spraying task performance in paddy farming activities. Res Agr. Eng.

Abstract: The commodity rice in Indonesia and the administration of rice fields are given particular focus by the government. Spraying activities are known to increase the risk of chemical exposure for farmers, resulting in a loss of working days for 3–7 days. It is necessary to carry out ergonomic interventions for spraying activities to make the activity safer for farmers. This research aims to identify the ergonomics and safety problems of spraying activities in rice field farming, to analyse and develop intervention parameters to solve issues in spraying activities, and to generate innovative design concepts to overcome spraying problems. Prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the functional requirements can be strong, moderate, weak, and zero (no ties). This relationship determines the technical importance of the rating. From the assessment of the relationship between the customer and the functional requirements, it can be seen which technical specifications should be prioritised for developing the product. An automated system is the technical specification that should be prioritised because it has the most significant weight on meeting the consumer needs.

Keywords: agriculture; human factors; musculoskeletal problems; risk; safety and health

The main types of jobs in the Indonesian population aged 15 and over are in the agriculture, forestry, and fisheries sectors, with 37 130,676 people or 28.33% of the population [Statistics Indonesia (BPS) 2024)]. The agricultural sector in Indonesia is very strategic because more than 70% of the primary income of the rural population comes from farming. The agricultural industry is vital and has the government's attention in order to improve the nation's economy and increase the productivity and welfare of farming families. However, rice farming activities in paddy fields pose a significant risk to one's occupational safety and health (Sudiajeng et al. 2024). Rice farmers face this risk (Walker-Bone and Palmer 2002) considering that rice farming in wet (irrigated) and dry (rainfed) rice fields in Indonesia is operated traditionally. Rice farming in other Southeast Asian Countries has almost the

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same characteristics as its management in Indonesia (Akbar et al. 2023). The countries want to improve the rice paddy farmers' performance because rice is the countries staple food. In Indonesia, the cultivation and management of rice paddies are a significant part of life and receive special attention and support from the government. The policy and concerns relate to the food security of the two countries. Rice field activities in both countries have the same stages, starting from the land preparation, seed nursery, nurseries, planting, maintenance (fertilising and spraying), and harvesting. However, the spraying activity, a crucial part of the maintenance stage, is known to cause a risk of exposure to chemicals for farmers, resulting in a loss of working days for 3–7 days. This is a significant concern that necessitates ergonomic interventions for spraying activities to make farming activities safer for farmers (Nawi et al. 2016). An automated spraying technology is the chosen type of intervention because farmers need a safer spraying tool to prevent the risks. The intervention reduces the loss of working days in the agricultural sector and increases the productivity and performance of farmers. The results of this study significantly improve the rice paddy farmers' quality of life, underscoring the importance of this research.

Agricultural activities, both traditional and automated, using tools can be an ergonomic hazard and pose a risk to farmers. Many studies on ergonomics risk factors in agriculture have been carried out. The most dominant risk is work-related musculoskeletal disorders (WMSDs) on part or all of the body (Zanatta et al. 2021). WMSDs can occur in the upper part of the body (Harith et al. 2021; Mohamaddan et al. 2021) and lower part of the body (Hota et al. 2020). The literature states that all agricultural activities, including land preparation, seeding, planting, and maintenance/spraying, can become an ergonomic hazard (Zanatta et al. 2021), harvesting (Houshyar and Kim 2018; Harith et al. 2021; Thota et al. 2022). Activities that use machines can also become an ergonomic hazard (Kociolek et al. 2018). The risk factors associated with using agricultural machinery are related to vibration or vibration (Thota et al. 2022). The effect of vibration from using these tools is also felt in all parts of the body. This vibration can be the cause of musculoskeletal disorders (MSDs). Risk factors associated with odd postures are also a hazard for musculoskeletal disorders in farmers (Franco et al. 2020). Other physical factors are repetitive movements and excessive exertion (Hota et al. 2020; Harith et al. 2021). The environment and agricultural land are also referred to as another ergonomic hazard, especially concerning thermal factors (López-Martínez et al. 2018), which cause heat stress on farmers. Various ergonomic interventions to improve the quality of work and quality of life of farmers have been proposed and designed, including designing more ergonomic agricultural tools to reduce the exposure to vibrations (Thota et al. 2022), automatic ladders to minimise the risk of shoulder injuries in tall crop harvesting (Thamsuwan and Johnson 2022), farmer work shift arrangements (Mohamaddan et al. 2021), the application of the time of the farming protocol (Hota et al. 2020), the design of gloves for harvesting (Chauhan et al. 2020), the design of cooling jackets to overcome thermal discomfort (Del Ferraro et al. 2021), etc. Ergonomic interventions to minimise risks to occupational health and safety can also be carried out at the organisational or farmer group level. An example is education for farmers regarding safe work postures (Lee et al. 2021; Caffaro et al. 2022). This is one of the potential efforts required to improve the safety climate at the organisational level (Kjestveit et al. 2021).

Technology is essential in controlling ergonomic hazards in agriculture to reduce the risk of heat stress due to extreme and dangerous natural conditions for farmers. One that can be pursued is to design a weather network station capable of collecting data on environmental parameters related to the workers' welfare (López-Martínez et al. 2018); robots can also help humans work in a better way (Vasconez et al. 2019). In the era of Agriculture 4.0, information technology also plays a crucial role in agriculture, and various kinds of intelligent farming designs can be used (Klerkx et al. 2019). In addition to physical hazards, agricultural activities also have psychological hazards. As with the activities and workload on the non-agricultural activities, physical and mental demands are always present.

Farmers are also at risk of mental stress in traditional agricultural activities that depend on the season and rainfall. Therefore, a psychological approach must also be designed to minimise the ergonomic risks due to mental stress (Lee et al. 2021).

The spraying activity is recognised as having the chance to increase the chemical exposure for farmers, resulting in a loss of working days for 3–7 days.

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It is necessary to carry out ergonomic interventions for spraying activities so that these activities can be carried out more safely for farmers. A drone technology is the chosen type of intervention because it is a safe spraying tool that can prevent the risk of poisoning hazards to farmers. With this intervention, it is hoped that the loss of working days in the agricultural sector will be minimised and the productivity and performance of the farmers will be increased. The results of this study are expected to improve the quality of life of rice paddy farmers. Therefore, this study aims to identify the safety ergonomics of spraying activities in rice field farming and develop intervention parameters to solve the problems related to the spraying activities.

MATERIAL AND METHODS

The sample and location selection consider the appropriateness and obtainability of the observed activities. The study sample and respondents in Indonesia are located in Pawidean Village, Jatibarang, Indramayu, Indonesia. This research involved 30 farmers from Pawidean Village and 4 Indramayu district agricultural service officers as the respondents. The study was undertaken from November 1st 2022 to August 31st 2023. This study consists of two phases to achieve the research objectives described in Figure 1. The Ergonomics Risk Assessment is a framework for analysing ergonomic risk in an activity. This tool examined the ergonomic risk factors that cause work-related musculoskeletal disorder problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist investigates the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is thought to be the cause of the farmers' mental burden. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity improves. Persona techniques are in-depth interview techniques with experts. This interview technique was conducted to complete the information and input data obtained from the field observations. Benchmarking is an approach for identifying the best practices in product design development and improvement activities. The brainstorming technique for product design compares the reference products with the plans resulting from the research, which was helpful in the design criticism by mapping the advantages and disadvantages of the reference products. The house of quality in the quality function deployment is a tool that can translate consumer desires into technical characteristics in design. Figure 1 displays the research methodology.

Phase 1: Problem identification and risk assessment. Ergonomics Risk Assessment (Chander and Cavatorta 2017; Zelik et al. 2022) analyses the ergo-

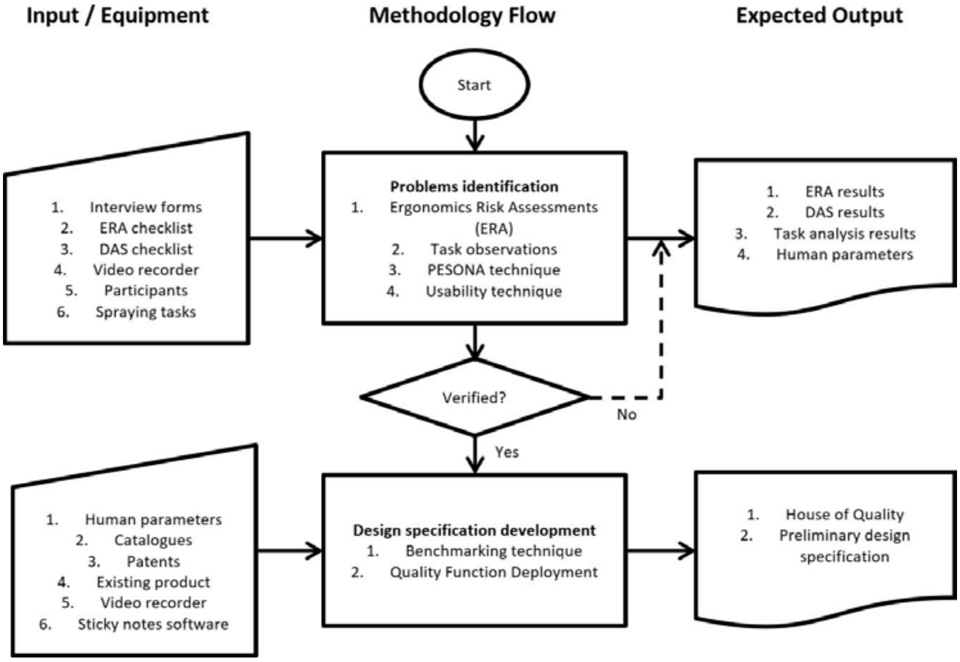

Figure 1. Research methodology

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nomic risk in an activity. This tool explored ergonomic risk factors that cause Work-related Muscle and Skeletal Disorders (WMSD) problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist (Bilgel and Bayram 2010) studied the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is claimed to be the cause of the mental burden on farmers. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity increases. Persona techniques are in-depth interview techniques with experts. The interview technique was conducted to complete the information and input the data obtained from the field observations.

Phase 2: Design specification development. A brainstorming technique for product design, comparing reference products with the plans from the research, was used for the design criticism, mapping the advantages and disadvantages of the reference products. Benchmarking is appropriate in product design development and improvement activities. Quality Function Deployment (QFD) (Finger and Lima-Junior 2022; Akao and Mazur 2003) is a tool that can translate consumer desires into technical characteristics in design.

RESULTS AND DISCUSSION

Work environment analysis. A lux meter measured the luminance level during the farmer's working time. The measurement results show that the average light level in the rice field area is 5 709 lux, with the highest light level being 6 057 lux. Noise is one of the environmental factors that can affect human work performance. During the spraying activity, it turned out that the noise level was classified as safe because it was below the hazard threshold. The sprayer farmers use in Pawidean Village does not cause any harmful noise. Like other parts of Indonesia, Pawidean Village is an area that gets quite a lot of sun exposure. At the time of the study, the UV Level Meter (Mobile version Lux Light Meter Pro, Canada) measures the UV exposure levels. At the time of observation, the average UV index measurement at the study site was level 3, or at a moderate level. The UV Index measurement was from 8.50 to 14.30 at the local time.

Farmers always consider the wind direction and speed in spraying activities to determine the best and safest spraying time. During observation, the wind blew at 9.5 km·h^{-1} from west to east. The right time for spraying rice plants is in the morning, around 7:00 to 9:00 p.m., or in the afternoon after *Ashar* time, around 3:30 to 5:00 p.m. At that time, predicting the wind direction and speed was easier. In addition, at that time, the stomata of the leaves were wide open because the temperature was not too high. In high-temperature environments, leaf stomata close, and spraying is not effective.

Spraying activity analysis. The following in Figure 2 shows the position of the farmer's body when the spraying activity is carried out. The picture

Figure 2. Body position spraying activity from the left side

Table 1 Work environment hazard analysis

Factor*	Measuring Tool	Result	Hazard risk level measurement
Lighting	lux meter	the average level is 5 709 lux, with the highest level of illumination at 6057 lux	natural lighting, safe
Noise	sound level meter	average 47.6 dBA during the spraying activity	low
Temperature	thermometer	average 30 ˚C	safe
UV Exposure	UV level meter	level 3	moderate
Wind	anemometer	the speed is 9.5 km·h^{-1} from West to East	

*result of hazard risk level measurement

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is taken from the farmer's left side to indicate the role of the farmer's arm—the farmer's right hand controls the sprayer, which is about 1–1.5 m long. The atomiser is a tube carried on the back with a shoulder strap.

There are three types of spray equipment currently used by farmers. To make it easier to compare their specifications, they are called types A, B, and C. Table 2 shows a comparison of the specifications of the spraying equipment. Figures 3 and 4 illustrate the diverse types of hand-pump sprayers utilized in Pawidean Village, showcasing their different designs and functionalities as they adapt to the local agricultural practices.

In analysing the use of the current spraying kit, some challenges must be overcome related to the detailed understanding of the technical specifications of the spraying equipment. Data were collected by investigating the product specifications from the manufacturers' and sellers' websites. The respondents did not care about the detailed technical specifications of the sprayer because the considerations in choosing a sprayer were based on the price, tank capacity, and power used, and whether it was necessary to use a battery or a manual pump.

The respondents' education backgrounds were elementary and junior high school. This is the general profile of traditional farmers in Indonesia who have a low educational background. Besides that, the farmers in Pawidean village are, on average, the elderly and have been farmers for tens of years. In this research, it was identified that they have been farming for more than ten years.

Table 2 Comparison of the specifications of spraying equipment currently used

Factors	Spraying equipment		
	type A	type B	type C
Capacity	16 L	20 L	16, 20, 17 L
Power	Rechargeable battery 12V – 8 Ah	Mixed gasoline and oil 2Stroke (25 : 1)	Power Rechargeable battery 12V – 8Ah mixed gasoline and oil 2Tak (25:1) Human
Price	IDR 995,000	IDR 1,699,900	Price IDR 995,000 IDR 1,699,900 IDR 540,000
Carrying technique	carried	carried	Moving procedure: Carried
Tube materials	Polypropylene (PP)	Tank Baffle Design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs.	Polypropylene (PP) tube material Tank Baffle Design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs. stainless steel
Pump models	Diaphragm pump with speed control		
Pump pressure	1–4 kg·cm^{-2}	5–25 (kg·f·cm^{-2})	Pump model Diaphragm pump with speed control
Spray lances	Telescopic spray lances		Pump pressure 1–4 kg·cm^{-2} 5–25 (kg·cm^{-2})
Nozzles	T-jets; 1&4 holes hollow cones		Spray lances Telescopic spray lances.
Application	Herbicide, Liquid Insecticide	Pest Medicine, Liquid Fertilisation	T-jet nozzles; - & 4-hole hollow cones
Dimensions	L – × w – × h – 395 × 220 × 151 mm	40 cm × 36 cm × 70 cm	Application Herbicide, Liquid Insecticide Pest Medicine, Disinfectant Liquid Fertiliser, Pest Medicine, Liquid Fertiliser

Value Added/ Advantage	16 L	Equipped with: Smart cable clip = a clip designed to tidy up the cables on the machine so there is no cable twist and protect the cord (Clips can be moved). Deep strainer basket = filtering tool/basket designed deeper so that it is faster for filtering and filling into the tank.	Dimensions: Length =395 mm Width = 220 mm Height = 151 mm

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Figure 3. Hand-pumped manual sprayer

There were problems regarding the regeneration of the farming profession in Indonesia, where the children of farmers tend not to become farmers like their parents because the traditional farming system in Indonesia is difficult and expensive

Figure 4. Variations of spray tools used by pawidean village farmers

(Sari et al. 2024) managing the trade-offs between economic and ecological targets. Serious games can be abstract and generic, or more complex and specific. They can be used to raise awareness, increase shared understanding of options and risks, and/or commitment to common goals.\nOBJECTIVE\nWe here aim to clarify design principles applied in the FORCES game (Farmer Options and its Risk in Complex Ecological-Social systems). Even though Indonesia's agricultural challenges are enormous, farmers' children were encouraged to get a higher education and work in the industry. With an ageing farmer demographic, adaptation of agricultural technologies becomes difficult. In spraying activities, the local Department of Agriculture has socialised the use of agricultural drones to assist rice plant maintenance activities. Still, there are obstacles to the acceptance of this technology. The following is a list of reasons why the survey found adaptation to the use of agricultural technology in Indramayu. First, using drones is a hassle because farmers cannot do it whenever they feel it is necessary. Secondly, farmers think that spraying with drones causes spraying drugs to be more wasteful because they do not target plants appropriately. A spraying distance that is too far from the plant causes the spray drug not to be absorbed optimally. Finally, spraying with drones is impractical for pest control because it does not reach the stems and roots. This is caused by the position of the spray from above, while the pests are often in the stems and roots of plants.

Usability analysis of the spray equipment currently used. A questionnaire was developed to evaluate the use of the current agricultural spraying equipment. This questionnaire was filled in by three farmers who routinely sprayed. Two respondents use a battery sprayer daily, while one uses a manual pump sprayer. Both were asked for their opinion to assess the usefulness of the sprayer. An ease of use analysis is needed to provide an overview of the interaction between the farmers and the spray equipment. A product interacts more closely with humans if the level of usability is good. The current spray equipment seems to have good usability and ease of use. This convenience seems to satisfy the users, both from the first time of service to routine use. 66.7% of respondents stated that the sprayer they are using now helps them spray the targeted paddy fields. The remaining 33.3% have a neutral opinion, which can be in-

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terpreted to mean that the current sprayer does not always help. All the respondents gave neutral answers to whether the current sprayer helps them to spray daily. This means that spraying is not undertaken every day.

100% of respondents stated that the sprayer, which is now helpful in spraying their rice fields, can be easily controlled by farmers for all rice fields and makes spraying activities easier. In the statement that the spray equipment can save working time, 66.7% of respondents disagreed, and 33.3% agreed. The current sprayer may not be able to meet the expected uptime-saving requirements. 33.3% of respondents stated that their spray equipment was not able to meet their needs.

Ergonomic risk analysis. The ergonomic risks referred to in this study are the risks of work-related musculoskeletal disorders suffered by farmers. Data regarding ergonomic risk were recorded for six respondents, all active farmers in Pawidean village. The respondents, apart from spraying, also carried out other agricultural tasks. The farmers' working hours vary, depending on their preferences and habits in carrying out activities. 100% of respondents work with their right hand, and their work experience is at least five years. Mental fatigue mainly occurs infrequently, and physical fatigue mostly occurs frequently. In the last year, 100% have felt pain/pain/discomfort related to their agricultural activities.

Farmer's mental load analysis. The mental load is identified and measured using the 42 item depression anxiety and stress scale using Depression, Anxiety, Depression Anxiety Stress Scales (DASS 42) questionnaire. Structured interviews and discussions were used. The surveyor obtained information about what the respondents felt related to their work in this observation – in this case, related to the agricultural activity. Forty-two symptoms of exposure to mental overload were identified and confirmed to the respondent, whether they had been experienced or not, and how often these symptoms occurred. The results of measuring the depression level of farmers in Pawidean village show that the respondent's answer mode shows a scale of 0–1. This indicates that there are no indications of depression in farmers. Measuring the Pawidean village farmers' anxiety levels shows a scale of 0–3. This suggests that farmers feel no indication of anxiety. Measurement of the stress level of Pawidean village farmers shows a scale of 0–1. This indicates that there are no indications of stress on the farmers.

Depression. One symptom indicator is feeling no longer strong enough to carry out activities, with a value of 1 (sometimes). If related to the results of the interviews with the farmers, most farmers are over 50 years old and have concerns that no one continues their work as farmers.

Anxiety. Some measurable anxiety symptoms are dry mouth, fatigue, sweating, and behaviour for no noticeable reason. The observed farmer activity was spraying once every ten days. Based on the results of the interviews with the farmers, the triggers for their anxiety are concerns about the crop/harvest and fatigue in spraying with a large amount of land. The sprayers owned by the farmers are less ergonomic.

Stress. Anxiety arises primarily due to the harvest.

Agricultural spraying equipment benchmarking. Spray equipment with drone technology in Indonesia has not been widely implemented because most rice farms use traditional labour-intensive systems. Drone technologies for agriculture have many uses, including plant health monitoring, planting and nursery care, the treatment and spraying of plants, and pollination. Unfortunately,

Table 3 Problems of Using Drone Spraying

No	Constraint	Source
1	Farmers are still not aware of the role of drones in helping their work	Simatupang et al. (2021), observation
2	Prices are still relatively expensive	Simatupang et al. (2021), observation
3	Difficult drone maintenance	Simatupang et al. (2021)
4	Not a practitioner because they must use the services of a third-party	observation
5	Availability of drone rental services is limited or non-existent	observation
6	Ownership of drones by farmers is not yet possible	observation
7	There must be training for drone operation	observation

8	The pesticide spraying was not on target, and it was wasting	survey results
9	It is not easy to spray the parts of the plant that are close to the roots.	survey results

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Table 4 Identification of the needs for the agricultural sprayer

Current spraying constraint	Farmers' expectations of the spraying equipment	Identification of needs
Heavy spray equipment, resulting in body aches	Want a lighter sprayer	Light sprayer
The wind is often challenging to predict the direction and speed	Want a tool that can read the direction and speed of the wind when spraying	The sprayer can determine the wind direction and wind speed
Often drunk due to drug spray poisoning	Want a safer sprayer	Spray equipment does not interfere with health
Plant	Want a spray tool that can reach up to	Spray equipment can access parts of the plant that are difficult to reach
Pests are often on the stems and near the roots	shadows and near roots	Spray equipment can save the use of pesticides
The prices are high because sprays are destroyed in the wind	Want a spray tool that is more efficient and right on target to be more efficient in using the poison spray?	The sprayer is easy to use
Not all farmers are skilled at spraying	Want a tool that is easier to use so everyone can do the spraying activity?	Long lasting sprayer

the adaptation of drone technologies to agriculture has encountered many obstacles. The reason is that drone spraying technologies still have many limitations. The use of drones is very dependent on weather conditions. Spraying using a drone must be undertaken when the weather is sunny and the wind speed is low. Identification of the difficulties in using drone spraying was carried out through literature studies and observations. The results are shown in Table 3.

In Indonesia, drones are used more on oil palm, acacia, and tea plantations. In addition to spraying, the farmers operate drones to map the plantation land. Modern farmers use spray drones for liquid fertiliser applications and pest control. The type of pest also determines the type of poison used. Rats, insects, and caterpillars are the most common pests. A discussion with an agricultural drone supplier validates the problems surrounding using drones for agriculture. Spraying with drones is often not on target for the types of pests hiding under the leaves. Therefore, the spraying intervention must concern not only the design of the nozzle, but also the dose and type of poison used. The opening of the spraying nozzle must be adjustable so that the strength and dosage of the spray drug are also suitable for plant problems. The role of farmer cooperatives could solve the problem of financing and renting drones for agriculture in Indonesia. Individual ownership of paddy fields is generally an obstacle to adaptation to the use of drones due to the high cost. Table 4 identifies the need for agricultural sprayers.

Consumer needs are the basis for determining the functional needs of agricultural sprayers. The consumer needs the data in Table 4, which is then translated into quality function deployment (QFD). QFD is a design planning process driven by customer requirements (Goetsch and Davis 2016). The QFD stages are presented in Figure 5. The following analysis of the stages produces twelve functional requirements for agrarian spray equipment: dimension, materials, weight, automated system, spray speed, spraying height, number of rotors, tank volume, area efficiency per flight, flight radius, droplet size, and nozzle quantity.

The prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the operational requirements is vital, moderate, weak, and zero (no ties). This relationship determines the technical importance rating. From assessing the relationship between the customer and the functional requirements, we detect which technical specifications are the priority in order to develop the product. An automated system is the technical specification that is the priority because it has the most significant weight on meeting the consumer needs. The following sequence is droplet size and nozzle quantity. The benchmarking

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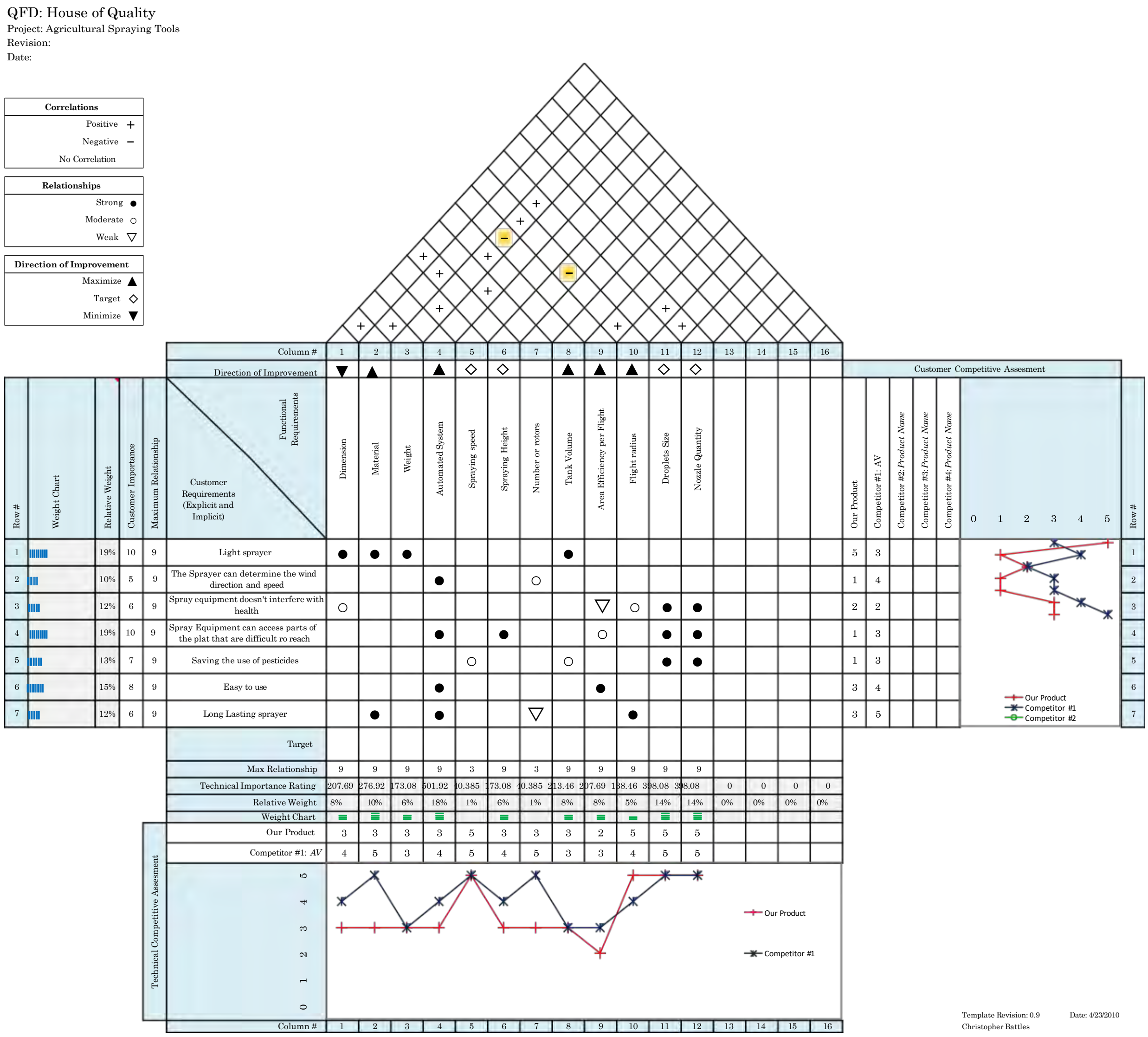

Figure 5. House of quality

analysis of the competitor products determines the strengths and weaknesses of the product. Consumers compare the product with competitors' products when it has entered the market. Product designers are required to anticipate this competition.

The benchmarking analysis of competitor products determines the strengths and weaknesses of the product being developed. Consumers compare the moulded product with the competitors' products when it has entered the market. Product designers are required to anticipate this competition.

CONCLUSION

An ergonomic risk is found in maintaining rice plants, specifically the risk of musculoskeletal disorders. The agricultural work environment exposes farmers to hazards, especially related to the light, wind, and UV radiation. There was no excessive mental burden on the agricultural work despite the many difficulties faced by the farmers. The sprayer currently used by the farmers is a sprayer that is carried on the shoulders and back, operated by battery power and a manual pump. In general, the farmers are satisfied with the use of this sprayer. However, there is still an expectation for the availability of alternative spraying equipment that is safer, more efficient, and easier to use. Mapping the need for agricultural spraying equipment using a house of quality shows that farmers consider spray equipment that is light and can reach the most difficult parts of the rice plant. These two needs can be seen

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from the results of the weighting of the needs, obtaining the highest weight, namely 19%. The technical specifications of an ergonomic sprayer to answer this need are the number of nozzles on the sprayer and the size of the produced droplets. Each of these specifications has a weight of 14%.

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Ergonomic investigation on spraying task performance in paddy farming activities

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Abstract: The commodity rice in Indonesia and the administration of rice fields are given particular focus by the government. Spraying activities are known to increase the risk of exposure to chemicals for farmers, resulting in a loss of working days for 3–7 days. It is necessary to carry out ergonomic interventions for spraying activities to make the activity safer for farmers. This research aims to identify the ergonomics and safety problems of spraying activities in rice field farming, to analyse and develop intervention parameters to solve issues in spraying activities, and to generate innovative design concepts to overcome spraying problems. Prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the functional requirements can be strong, moderate, weak, and zero (no ties). This relationship determines the technical importance of the rating. From the assessment of the relationship between the customer and the functional requirements, it can be seen which technical specifications should be prioritised for developing the product. An automated system is the technical specification that should be prioritised because it has the most significant weight on meeting the consumer needs.

Keywords: agriculture; ergonomics; farming; risk; spraying task

The main types of jobs in the Indonesian population aged 15 and over are in the agriculture, forestry, and fisheries sectors, with 37 130,676 people or 28.33% of the population [Statistics Indonesia (BPS) 2024)]. The agricultural sector in Indonesia is very strategic because more than 70% of the primary income of the rural population comes from farming. The agricultural industry is vital and has the government's attention in order to improve the nation's economy and increase the productivity and welfare of farming families. However, rice farming activities in paddy fields pose a significant risk to one's occupational safety and health (Sudiajeng et al. 2024). Rice farmers face this risk (Walker-Bone and Palmer 2002) considering that rice farming in wet (irrigated) and dry (rainfed) rice fields in Indonesia is operated traditionally. Rice farming in other Southeast Asian Countries has almost the

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same characteristics as its management in Indonesia (Akbar et al. 2023). The countries want to improve the rice paddy farmers' performance because rice is the countries staple food. In Indonesia, the cultivation and management of rice paddies are a significant part of life and receive special attention and support from the government. The policy and concerns relate to the food security of the two countries. Rice field activities in both countries have the same stages, starting from the land preparation, seed nursery, nurseries, planting, maintenance (fertilising and spraying), and harvesting. However, the spraying activity, a crucial part of the maintenance stage, is known to cause a risk of exposure to chemicals for farmers, resulting in a loss of working days for 3–7 days. This is a significant concern that necessitates ergonomic interventions for spraying activities to make farming activities safer for farmers (Nawi et al. 2016). An automated spraying technology is the chosen type of intervention because farmers need a safer spraying tool to prevent the risks. The intervention reduces the loss of working days in the agricultural sector and increases the productivity and performance of farmers. The results of this study significantly improve the rice paddy farmers' quality of life, underscoring the importance of this research.

Agricultural activities, both traditional and automated, using tools can be an ergonomic hazard and pose a risk to farmers. Many studies on ergonomics risk factors in agriculture have been carried out. The most dominant risk is work-related musculoskeletal disorders (WMSDs) on part or all of the body (Zanatta et al. 2021). WMSDs can occur in the upper part of the body (Harith et al. 2021; Mohamaddan et al. 2021) and lower part of the body (Hota et al. 2020). The literature states that all agricultural activities, including land preparation, seeding, planting, and maintenance/spraying, can become an ergonomic hazard (Zanatta et al. 2021), harvesting (Houshyar and Kim 2018; Harith et al. 2021; Thota et al. 2022). Activities that use machines can also become an ergonomic hazard (Kociolek et al. 2018). The risk factors associated with using agricultural machinery are related to vibration or vibration (Thota et al. 2022). The effect of vibration from using these tools is also felt in all parts of the body. This vibration can be the cause of musculoskeletal disorders (MSDs). Risk factors associated with odd postures are also a hazard for musculoskeletal disorders in farmers (Franco et al. 2020). Other physical factors are repetitive movements and excessive exertion (Hota et al. 2020; Harith et al. 2021). The environment and agricultural land are also referred to as another ergonomic hazard, especially concerning thermal factors (López-Martínez et al. 2018), which cause heat stress on farmers. Various ergonomic interventions to improve the quality of work and quality of life of farmers have been proposed and designed, including designing more ergonomic agricultural tools to reduce the exposure to vibrations (Thota et al. 2022), automatic ladders to minimise the risk of shoulder injuries in tall crop harvesting (Thamsuwan and Johnson 2022), farmer work shift arrangements (Mohamaddan et al. 2021), the application of the time of the farming protocol (Hota et al. 2020), the design of gloves for harvesting (Chauhan et al. 2020), the design of cooling jackets to overcome thermal discomfort (Del Ferraro et al. 2021), etc. Ergonomic interventions to minimise risks to occupational health and safety can also be carried out at the organisational or farmer group level. An example is education for farmers regarding safe work postures (Lee et al. 2021; Caffaro et al. 2022). This is one of the potential efforts required to improve the safety climate at the organisational level (Kjestveit et al. 2021).

Technology is essential in controlling ergonomic hazards in agriculture to reduce the risk of heat stress due to extreme and dangerous natural conditions for farmers. One that can be pursued is to design a weather network station capable of collecting data on environmental parameters related to the workers' welfare (López-Martínez et al. 2018); robots can also help humans work in a better way (Vasconez et al. 2019). In the era of Agriculture 4.0, information technology also plays a crucial role in agriculture, and various kinds of intelligent farming designs can be used (Klerkx et al. 2019). In addition to physical hazards, agricultural activities also have psychological hazards. As with the activities and workload on the non-agricultural activities, physical and mental demands are always present. Farmers are also at risk of mental stress in traditional agricultural activities that depend on the season and rainfall. Therefore, a psychological approach must also be designed to minimise the ergonomic risks due to mental stress (Lee et al. 2021).

The spraying activity is recognised as having the chance to increase the chemical exposure for farmers, resulting in a loss of working days for 3–7 days.

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It is necessary to carry out ergonomic interventions for spraying activities so that these activities can be carried out more safely for farmers. A drone technology is the chosen type of intervention because it is a safe spraying tool that can prevent the risk of poisoning hazards to farmers. With this intervention, it is hoped that the loss of working days in the agricultural sector will be minimised and the productivity and performance of the farmers will be increased. The results of this study are expected to improve the quality of life of rice paddy farmers. Therefore, this study aims to identify the safety ergonomics of spraying activities in rice field farming and develop intervention parameters to solve the problems related to the spraying activities.

MATERIAL AND METHODS

The sample and location selection consider the appropriateness and obtainability of the observed activities. The study sample and respondents in Indonesia are located in Pawidean Village, Jatibarang, Indramayu, Indonesia. This research involved 30 farmers from Pawidean Village and 4 Indramayu district agricultural service officers as the respondents. The study was undertaken from November 1st 2022 to August 31st 2023. This study consists of two phases to achieve the research objectives described in Figure 1. The Ergonomics Risk Assessment (software?) is a tool for analysing ergonomic risk in an activity. This tool examined the ergonomic risk factors that cause work-related musculoskeletal disorder problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist investigates the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is thought to be the cause of the farmers' mental burden. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity improves. Persona techniques are in-depth interview techniques with experts. This interview technique was conducted to complete the information and input data obtained from the field observations. Benchmarking is an approach for identifying the best practices in product design development and improvement activities. The brainstorming technique for product design compares the reference products with the plans resulting from the research, which was helpful in the design criticism by mapping the advantages and disadvantages of the reference products. The house of quality in the quality function deployment is a tool that can translate consumer desires into technical characteristics in design. Figure 1 displays the research methodology.

Phase 1: Problem identification and risk assessment. Ergonomics Risk Assessment (Chander and Cavatorta 2017; Zelik et al. 2022) analyses the

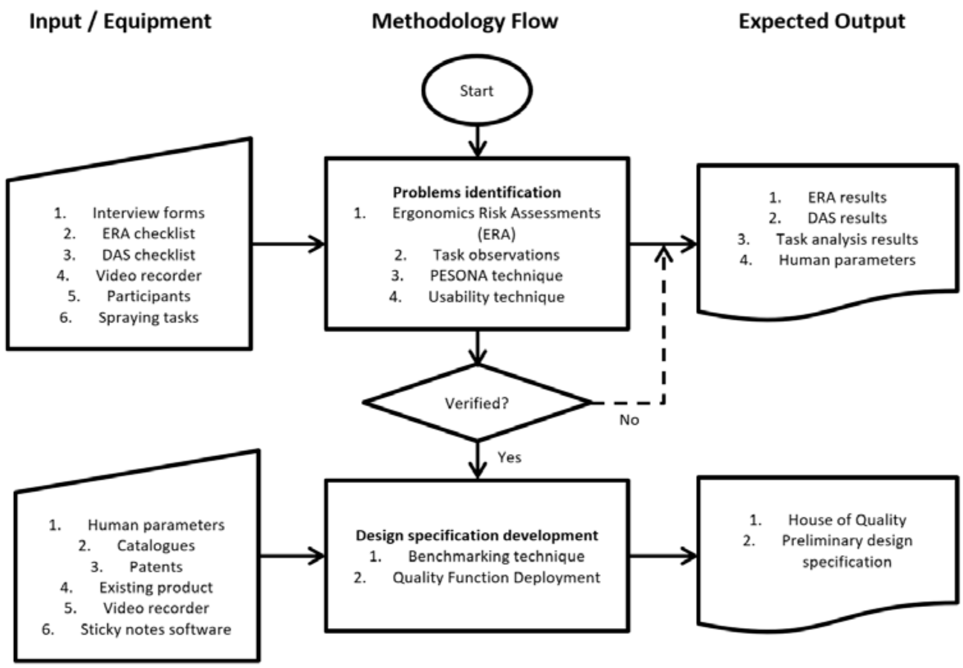

Figure 1. Research methodology

ergo-

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nomic risk in an activity. This tool explored ergonomic risk factors that cause Work-related Muscle and Skeletal Disorders (WMSD) problems. These factors include the body posture, loading, and frequency of the repetition of movements. The Depression Anxiety Stress Checklist (Bilgel and Bayram 2010) studied the farmers' mental and cognitive load when carrying out agricultural activities. It is known that farmers cannot control many variables in agriculture, and this is claimed to be the cause of the mental burden on farmers. Excessive cognitive load is one of the ergonomic risk factors that must be resolved to improve the farmers' quality of life so that their productivity increases. Persona techniques are in-depth interview techniques with experts. The interview technique was conducted to complete the information and input the data obtained from the field observations.

Phase 2: Design specification development. A brainstorming technique for product design, comparing reference products with the plans from the research, was used for the design criticism, mapping the advantages and disadvantages of the reference products. Benchmarking is appropriate in product design development and improvement activities. Quality Function Deployment (QFD) (Finger and Lima-Junior 2022; Akao and Mazur 2003) is a tool that can translate consumer desires into technical characteristics in design.

RESULTS AND DISCUSSION

Work environment analysis. A lux meter measured the luminance level during the farmer's working time. The measurement results show that the average light level in the rice field area is 5 709 lux, with the highest light level being 6 057 lux. Noise is one of the environmental factors that can affect human work performance. During the spraying activity, it turned out that the noise level was classified as safe because it was below the hazard threshold. The sprayer farmers use in Pawidean Village does not cause any harmful noise. Like other parts of Indonesia, Pawidean Village is an area that gets quite a lot of sun exposure. At the time of the study, the UV Level Meter (producer, country) measures the UV exposure levels. At the time of observation, the average UV index measurement at the study site was level 3, or at a moderate level. The UV Index measurement was from 8.50 to 14.30 at the local time.

Farmers always consider the wind direction and speed in spraying activities to determine the best and safest spraying time. During observation, the wind blew at 9.5 km·h^{-1} from west to east. The right time for spraying rice plants is in the morning, around 7:00 to 9:00 p.m., or in the afternoon after *Ashar* time, around 3:30 to 5:00 p.m. At that time, predicting the wind direction and speed was easier. In addition, at that time, the stomata of the leaves were wide open because the temperature was not too high. In high-temperature environments, leaf stomata close, and spraying is not effective.

Spraying activity analysis. The following in Figure 2 shows the position of the farmer's body when the spraying activity is carried out. The picture

Figure 2. Body position spraying activity from the left side

Table 1 Work environment hazard analysis

Factor*	Measuring Tool	Result	Hazard risk level measurement
Lighting	lux meter	the average level is 5 709 lux, with the highest level of illumination at 6057 lux	natural lighting, safe
Noise	sound level meter	average 47.6 dBA during the spraying activity	low
Temperature	thermometer	average 30 °C	safe
UV Exposure	UV level meter	level 3	moderate
Wind	anemometer	the speed is 9.5 km·h^{-1} from West to East	

*result of hazard risk level measurement

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is taken from the farmer's left side to indicate the role of the farmer's arm—the farmer's right hand controls the sprayer, which is about 1–1.5 m long. The atomiser is a tube carried on the back with a shoulder strap.

There are three types of spray equipment currently used by farmers. To make it easier to compare their specifications, they are called types A, B, and C. Table 2 shows a comparison of the specifications of the spraying equipment.

In analysing the use of the current spraying kit, some challenges must be overcome related to the detailed understanding of the technical specifications of the spraying equipment. Data were collected by investigating the product specifications from the manufacturers' and sellers' websites. The respondents did not care about the detailed technical specifications of the sprayer because the considerations in choosing a sprayer were based on the price, tank capacity, and power used, and whether it was necessary to use a battery or a manual pump.

The respondents' education backgrounds were elementary and junior high school. This is the general profile of traditional farmers in Indonesia who have a low educational background. Besides that, the farmers in Pawidean village are, on average, the elderly and have been farmers for tens of years. In this research, it was identified that they have been farming for more than ten years.

Table 2 Comparison of the specifications of spraying equipment currently used

???	Spraying equipment		
	type A	type B	type C
Capacity	16 L	20 L	16, 20, 17 L
Power	Rechargeable battery 12V – 8 Ah	Mixed gasoline and oil 2Stroke (25 : 1)	Power Rechargeable battery 12V – 8Ah mixed gasoline and oil 2Tak (25:1) Human
Price	IDR 995,000	IDR 1,699,900	Price IDR 995,000 IDR 1,699,900 IDR 540,000
Carrying technique	carried	carried	Moving procedure Carried Carried Carried
Tube materials	Polypropylene (PP)	Tank Baffle Design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs.	Polypropylene (PP) tube material Tank Baffle Design = a tank designed to have a partition inside the tank that aims to lower/break the shock of water when it runs. stainless steel
Pump models	Diaphragm pump with speed control		
Pump pressure	1–4 kg·cm^{-2}	5–25 (kg·f·cm^{-2})	Pump model Diaphragm pump with speed control
Spray lances	Telescopic spray lances		Pump pressure 1–4 kg·cm^{-2} 5–25 (kg·cm^{-2})
Nozzles	T-jets; 1&4 holes hollow cones		Spray lances Telescopic spray lances.
Application	Herbicide, Liquid Insecticide	Pest Medicine, Liquid Fertilisation	T-jet nozzles; - & 4-hole hollow cones
Dimensions	L – × w – × h – 395 × 220 × 151 mm	40 cm × 36 cm × 70 cm	Application Herbicide, Liquid Insecticide Pest Medicine, Disinfectant Liquid Fertiliser, Pest Medicine, Liquid Fertiliser
Value Added/ Advantage	16 L	Equipped with: Smart cable clip = a clip designed to tidy up the cables on the machine so there is no cable twist and protect the cord (Clips can be moved). Deep strainer basket = filtering tool/basket designed deeper so that it is faster for filtering and filling into the tank.	Dimensions: L – 395 mm × W – 220 mm × H – 151 mm 40 cm × 36 cm × 70 cm 35 × 20 × 50 cm

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Figure 3. Hand-pumped manual sprayer

There were problems regarding the regeneration of the farming profession in Indonesia, where the children of farmers tend not to become farmers like their parents because the traditional farming system in Indonesia is difficult and expensive (Sari et al. 2024) managing the trade-offs between economic and ecological targets. Serious games can be abstract and generic, or more complex and specific. They can be used to raise awareness, increase shared understanding of options and risks, and/or commitment to common goals.\nOBJECTIVE\nWe here aim to clarify design principles applied in the FORCES game (Farmer Options and its Risk in Complex Ecological-Social systems). Even though Indonesia's agricultural challenges are enormous, farmers' children were encouraged to get a higher education and work in the industry. With an ageing farmer demographic, adaptation of agricultural technologies becomes difficult. In spraying activities, the local Department of Agriculture has socialised the use of agricultural drones to assist rice plant maintenance activities. Still, there are obstacles to the acceptance of this technology. The following is a list of reasons why the survey found adaptation to the use of agricultural technology in Indramayu. First, using drones is a hassle because farmers cannot do it whenever they feel it is necessary. Secondly, farmers think that spraying with drones causes spraying drugs to be more wasteful because they do not target plants appropriately. A spraying distance that is too far from the plant causes the spray drug not to be absorbed optimally. Finally, spraying with drones is impractical for pest control because it does not reach the stems and roots. This is caused by the position of the spray from above, while the pests are often in the stems and roots of plants.

Figure 4. Variations of spray tools used by pawidean village farmers

Usability analysis of the spray equipment currently used. A questionnaire was developed to evaluate the use of the agricultural spraying equipment currently used. This questionnaire was filled in by three farmers who routinely sprayed. Two respondents use a battery sprayer daily, while one uses a manual pump sprayer. Both were asked for their opinion to assess the usefulness of the sprayer. An ease of use analysis is needed to provide an overview of the interaction between the farmers and the spray equipment. A product interacts more closely with humans if the level of usability is good. The current spray equipment seems to have good usability and ease of use. This convenience seems to satisfy the users, both from the first time of service to routine use. 66.7% of respondents stated that the sprayer they are using now helps them spray the targeted paddy fields. The remaining 33.3% have a neutral opinion, which can be in-

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terpreted to mean that the current sprayer does not always help. All the respondents gave neutral answers to whether the current sprayer helps them to spray daily. This means that spraying is not undertaken every day.

100% of respondents stated that the sprayer, which is now helpful in spraying their rice fields, can be easily controlled by farmers for all rice fields and makes spraying activities easier. In the statement that the spray equipment can save working time, 66.7% of respondents disagreed, and 33.3% agreed. The current sprayer may not be able to meet the expected uptime-saving requirements. 33.3% of respondents stated that their spray equipment was not able to meet their needs.

Ergonomic risk analysis. The ergonomic risks referred to in this study are the risks of work-related musculoskeletal disorders suffered by farmers. Data regarding ergonomic risk were recorded for six respondents, all active farmers in Pawidean village. The respondents, apart from spraying, also carried out other agricultural tasks. The farmers' working hours vary, depending on their preferences and habits in carrying out activities. 100% of respondents work with their right hand, and their work experience is at least five years. Mental fatigue mainly occurs infrequently, and physical fatigue mostly occurs frequently. In the last year, 100% have felt pain/pain/discomfort related to their agricultural activities.

Farmer's mental load analysis. The mental load is identified and measured using the 42 item depression anxiety and stress scale (DASS-42) questionnaire. Structured interviews and discussions were used. The surveyor obtained information about what the respondents felt related to their work in this observation – in this case, related to the agricultural activity. Forty-two symptoms of exposure to mental overload were identified and confirmed to the respondent, whether they had been experienced or not, and how often these symptoms occurred. The results of measuring the depression level of farmers in Pawidean village show that the respondent's answer mode shows a scale of 0–1. This indicates that there are no indications of depression in farmers. Measuring the Pawidean village farmers' anxiety levels shows a scale of 0–3. This suggests that farmers feel no indication of anxiety. Measurement of the stress level of Pawidean village farmers shows a scale of 0–1. This indicates that there are no indications of stress on the farmers.

Depression. One symptom indicator is feeling no longer strong enough to carry out activities, with a value of 1 (sometimes). If related to the results of the interviews with the farmers, most farmers are over 50 years old and have concerns that no one continues their work as farmers.

Anxiety. Some measurable anxiety symptoms are dry mouth, fatigue, sweating, and behaviour for no noticeable reason. The observed farmer activity was spraying once every ten days. Based on the results of the interviews with the farmers, the triggers for their anxiety are concerns about the crop/harvest and fatigue in spraying with a large amount of land. The sprayers owned by the farmers are less ergonomic.

Stress. Anxiety arises primarily due to the harvest.

Agricultural spraying equipment benchmarking. Spray equipment with drone technology in Indonesia has not been widely implemented because most rice farms use traditional labour-intensive systems. Drone technologies for agriculture have many uses, including plant health monitoring, planting and nursery care, the treatment and spraying of plants, and pollination. Unfortunately,

Table 3 Problems of Using Drone Spraying

No	Constraint	Source
1	Farmers are still not aware of the role of drones in helping their work	Simatupang et al. (2021), observation
2	Prices are still relatively expensive	Simatupang et al. (2021), observation
3	Difficult drone maintenance	Simatupang et al. (2021)
4	Not a practitioner because they must use the services of a third-party	observation
5	Availability of drone rental services is limited or non-existent	observation
6	Ownership of drones by farmers is not yet possible	observation
7	There must be training for drone operation	observation
8	The pesticide spraying was not on target, and it was wasting	survey results
9	It is not easy to spray the parts of the plant that are close to the roots.	survey results

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Table 4 Identification of the needs for the agricultural sprayer

Current spraying constraint	Farmers' expectations of the spraying equipment	Identification of needs
Heavy spray equipment, resulting in body aches	Want a lighter sprayer	Light sprayer
The wind is often challenging to predict the direction and speed	Want a tool that can read the direction and speed of the wind when spraying	The sprayer can determine the wind direction and wind speed
Often drunk due to drug spray poisoning	Want a safer sprayer	Spray equipment does not interfere with health
Plant	Want a spray tool that can reach up to	Spray equipment can access parts of the plant that are difficult to reach
Pests are often on the stems and near the roots	shadows and near roots	Spray equipment can save the use of pesticides
The prices are high because sprays are destroyed in the wind	Want a spray tool that is more efficient and right on target to be more efficient in using the poison spray?	The sprayer is easy to use
Not all farmers are skilled at spraying	Want a tool that is easier to use so everyone can do the spraying activity?	Long lasting sprayer

the adaptation of drone technologies to agriculture has encountered many obstacles. The reason is that drone spraying technologies still have many limitations. The use of drones is very dependent on weather conditions. Spraying using a drone must be undertaken when the weather is sunny and the wind speed is low. Identification of the difficulties in using drone spraying was carried out through literature studies and observations. The results are shown in Table 3.

In Indonesia, drones are used more on oil palm, acacia, and tea plantations. In addition to spraying, the farmers operate drones to map the plantation land. Modern farmers use spray drones for liquid fertiliser applications and pest control. The type of pest also determines the type of poison used. Rats, insects, and caterpillars are the most common pests. A discussion with an agricultural drone supplier validates the problems surrounding using drones for agriculture. Spraying with drones is often not on target for the types of pests hiding under the leaves. Therefore, the spraying intervention must concern not only the design of the nozzle, but also the dose and type of poison used. The opening of the spraying nozzle must be adjustable so that the strength and dosage of the spray drug are also suitable for plant problems. The role of farmer cooperatives could solve the problem of financing and renting drones for agriculture in Indonesia. Individual ownership of paddy fields is generally an obstacle to adaptation to the use of drones due to the high cost. Table 4 identifies the need for agricultural sprayers.

Consumer needs are the basis for determining the functional needs of agricultural sprayers. The consumer needs the data in Table 4, which is then translated into quality function deployment (QFD). QFD is a design planning process driven by customer requirements (Goetsch and Davis 2016). The QFD stages are presented in Figure 5. The following analysis of the stages produces twelve functional requirements for agrarian spray equipment: dimension, materials, weight, automated system, spray speed, spraying height, number of rotors, tank volume, area efficiency per flight, flight radius, droplet size, and nozzle quantity.

The prospective users assign importance weights to the twelve functional requirements. The light sprayer has the highest weight, meaning users need a lightweight sprayer. The relationship between the customer and the operational requirements is vital, moderate, weak, and zero (no ties). This relationship determines the technical importance rating. From assessing the relationship between the customer and the functional requirements, we detect which technical specifications are the priority in order to develop the product. An automated system is the technical specification that is the priority because it has the most significant weight on meeting the consumer needs. The following sequence is droplet size and nozzle quantity. The benchmarking

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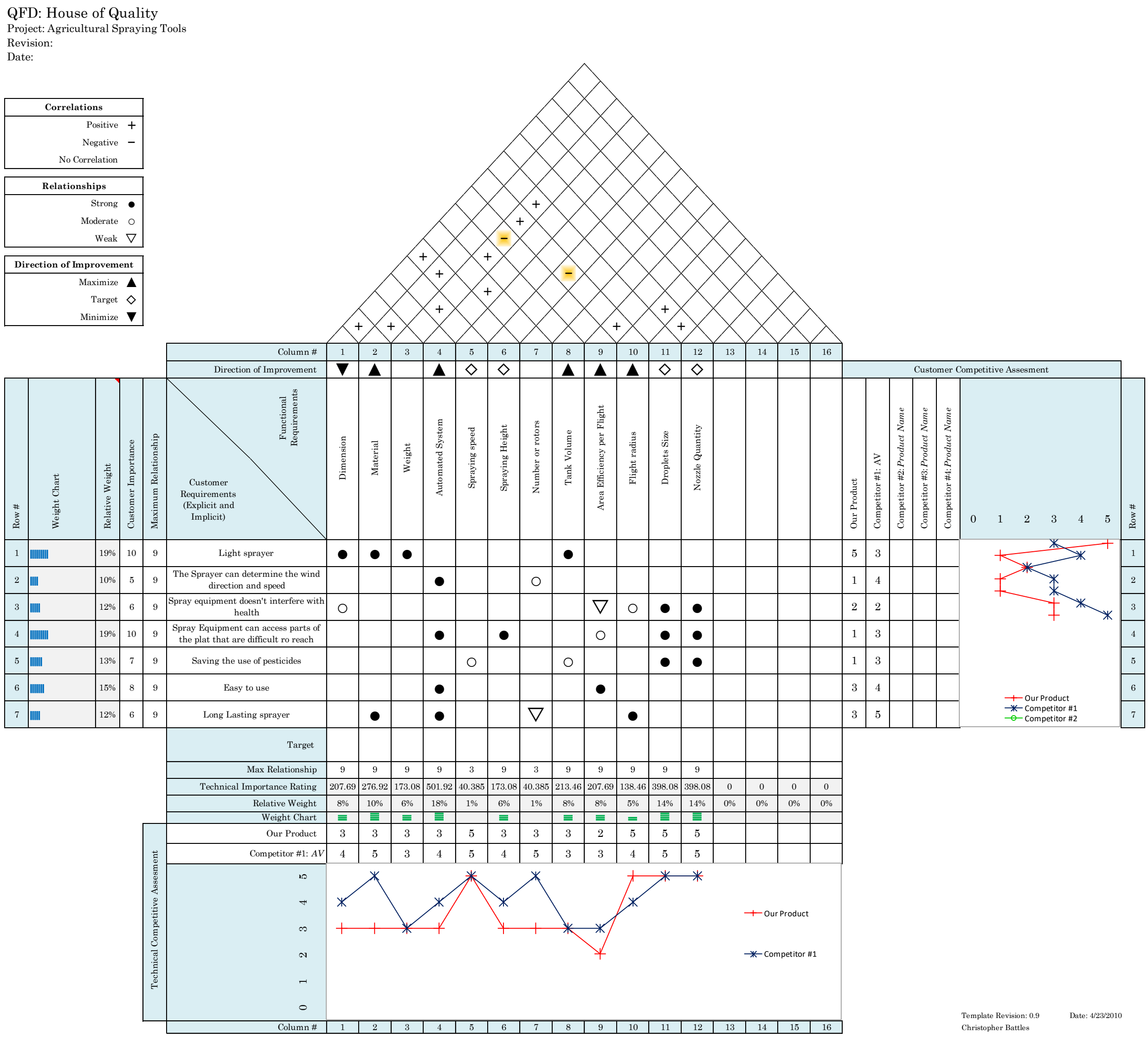

Figure 5. House of quality

analysis of the competitor products determines the strengths and weaknesses of the product. Consumers compare the product with competitors' products when it has entered the market. Product designers are required to anticipate this competition.

The benchmarking analysis of competitor products determines the strengths and weaknesses of the product being developed. Consumers compare the moulded product with the competitors' products when it has entered the market. Product designers are required to anticipate this competition.

CONCLUSION

An ergonomic risk is found in maintaining rice plants, specifically the risk of musculoskeletal disorders. The agricultural work environment exposes farmers to hazards, especially related to the light, wind, and UV radiation. There was no excessive mental burden on the agricultural work despite the many difficulties faced by the farmers. The sprayer currently used by the farmers is a sprayer that is carried on the shoulders and back, operated by battery power and a manual pump. In general, the farmers are satisfied with the use of this sprayer. However, there is still an expectation for the availability of alternative spraying equipment that is safer, more efficient, and easier to use. Mapping the need for agricultural spraying equipment using a house of quality shows that farmers consider spray equipment that is light and can reach the most difficult parts of the rice plant. These two needs can be seen

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from the results of the weighting of the needs, obtaining the highest weight, namely 19%. The technical specifications of an ergonomic sprayer to answer this need are the number of nozzles on the sprayer and the size of the produced droplets. Each of these specifications has a weight of 14%.

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