Research Article

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Field investigation of component failures for selected farm machinery used in small rice farming operations

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Abstract: Failure of farm machinery components is an undesirable event that often occurs during field operations and becomes a crucial problem facing rice farmers in Riau Province. The purpose of the research is to investigate the component type and failure frequency and find out the root causes of the component failures for selected farm machinery used by small rice farmers. The survey was carried out in three regencies of the province namely Kampar, Siak, and Indragiri Hulu from June to July 2022. The data were collected from personally interviewing 30 machine operators and 10 mechanics. Five types of farm machinery were selected for study, including mouldboard plows, rotary tillers, four-wheel tractors, rice transplanters, and combine harvesters. The machines have often experienced breakdowns on the field due to the failure of one or more components/parts. Mouldboard plows had the most component failures with 137 cases, followed by rotary tillers with 85 cases, and four-wheel tractors with 57 cases. There were 34 and 43 cases of component failures for rice transplanters and combine harvesters, respectively. The root causes of component failures were poor field conditions (30%), ignoring maintenance (22%), intensive use of machinery (21%), improper storage (14%), and unskilled operators (13%). The results recommend that machine operators must keep the work area clean before beginning operation, conduct regular maintenance, store farm machines inside and keep them clean from dust and filth, have the necessary training and experience to help reduce failures, and run their machines precisely at the maximum power levels to prevent needless strain and early failure.

Keywords: component failure, farm machinery, failure frequency, root cause

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1 Introduction

Agricultural mechanization, particularly in the use of machinery, is essential to mechanize the agricultural system today. Historically, the mechanization process has been dynamic, and farm machinery has become increasingly complex and powerful [1]. The current introduction of complex farm machinery has displaced more quickly power sources from the use of human and animal power to mechanical power [2–4] and later to automation technology [5] like agricultural robots [6,7] which has been increasingly relevant [8] under current conditions. The development of more complex and powerful machines has considerable potential for increasing maximum farm yield and greater efficiency. However, the negative impact of using farm machinery replaces human labour [9] and eventually reduces human labour [10,11].

The continued development of agricultural machinery with multi-functions like tractors and combine harvesters has led to making field operations easier so that most farm operations around the world are completely mechanized. Consequently, the use of modern technology resulted in the rapid growth of farm production [12,13] and has solved food scarcity problems in many developing countries [14]. Therefore, the major purposes of mechanization, like an increase in labour and land productivity, and a decrease in the cost of production, could be achieved [15–17] and reduce post-harvest loss during harvesting, threshing, and milling operations [18,19].

In the midst of increasingly advanced farm machinery, many farmers are facing many problems with the use of farm machinery. Breakdowns, which are field stoppages due to a sudden failure of a part [20], have often become crucial problems during field operations. As a major investment in the agricultural system [21] and one of the important capital inputs in agricultural production [22], the failure of farm machinery components can be awfully expensive [23–25] and have an impact on the cost of production [26]. Breakdowns and their impacts on the machines are the main causes of reductions in overall equipment performance [27]. Moreover, farm machines due to the nature of their work are exposed to a substantial risk of breakdowns.

Failure of machinery components is one of the main causes of field breakdowns that cause farm machinery to cease to operate and later delays in the production system [28]. A failure is defined as an inability of a component or system to perform its specified function in accordance with specified performance requirements [29,30]. Machine failure is a condition where the machine cannot operate optimally because of intentional or unintended causes [31]. The failure of machine components is difficult to predict because events often occur at random [32]. The failure, particularly during peak season, results in delays that lead to loss and inefficient utilization of labour [33]. The majority of machinery failures can be attributed to poor application, poor operating or maintenance practices and procedures, human error [34], and repair and maintenance capability and facilities [35]. Inadequate repair and maintenance facilities can cause delays in repair work and raise the price of spare parts [36]. Additionally, farm machines that are operated in a variety and poor field conditions can lead to more frequent failures.

The failure of agricultural machinery is still a major problem in Riau Province, Indonesia. The problem can be recognized from a survey carried out in 2007 [37] and in 2022 [38]. Both investigations focused only on breakdown cases without exploring in detail the root causes of the breakdowns. From the studies, the number of breakdowns has remained unchanged over the period and has even tended to increase in recent years. This means that with the increase in the types and number of farm machines used by farmers today, breakdown cases have also increased in the province. In some cases, and based on field investigations, farm machinery has been found to be permanently damaged before the end of its economic life. It will make the investment for farm machinery will not get a lot of benefits because of running out of machines.

Machinery component failures often occur in the field operation and the failure of some components of any farm machine is inevitable [39]. In general, failures can be classified into three basic types: early failures, random failures, and wear-out failures [40]. Although failure cannot be completely avoided, the related risks and effects may be minimized and controlled [41]. Therefore, this research attempts to investigate the component type and failure frequency and to find out the root cause of component failures for selected farm machinery. The result will be very useful to help small farmers overcome and prevent similar component failures in the future.

2 Materials and methods

2.1 Survey location

The study was conducted in three regions from twelve regencies in Riau Province, namely Kampar, Indragiri Hulu, and Siak (Figure 1). These locations are important areas of rice production centres and become the model for the extensive use of agricultural machinery in the province. The locations have plain land areas with similar geographical and climatic conditions. The paddy field in the rainfed region is very dominant with twice the cropping seasons every year. The main rice cropping season in the province is from November to March. During this season, the rainfall is high, so the water supply flowing into the rice fields is sufficient while the rice is growing. During on dry season, farmers may have trouble during April to October because there is not enough water to till their fields. But during these seasons, it is less predictable and shifts slightly when it starts and ends due to climate change. Farm tractors such as two-wheel tractors and four-wheel tractors that are used for the dry season must work hard to carry out tillage operations.

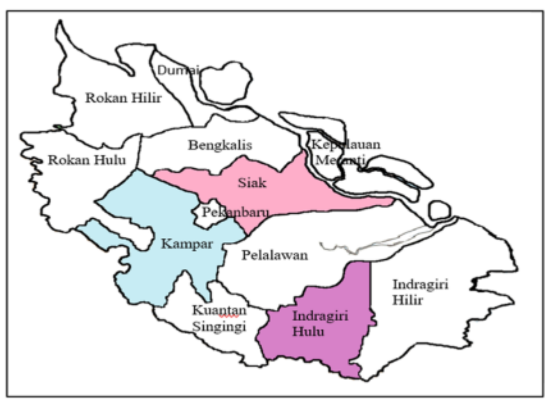

Figure 1: Map of Riau Province showing survey locations. Note: the colour area is the survey location. Note: The colour area is the survey location. Source: Statistical of Riau Province, 2023 (Modified Map).

2.2 Selection of farm machinery

Twenty-six farmer groups actively providing machine rental services will be selected and will manage at least five machine types. These five types of farm machines were then selected to be investigated, including mouldboard plows, rotary tillers, 4-wheel tractors, rice transplanters, and combine harvesters. They are the most popular machines among farmers and have been used more intensively in rice farming operations in Riau Province in recent years. Another reason is that the machines were often found to suffer failures of their components/parts, and these contributed to the breakdown events of the machine during field operation.

2.3 Data sources and analysis

This research mostly used primary data collected from machine operators and mechanics from June to July 2022. Thirty farmer operators (10 operators each regency) and 9 mechanics (3 mechanics each regency) with a total of 39 respondents were interviewed to collect primary data. Personal interviews and observations were conducted through field visits to the houses of farmer operators and sheds/workshops for mechanics. The primary data collected consisted of information about farm machinery: their types and number of component failures, and the root cause of component failures during field operations. The collected data were then tabulated and analysed using a descriptive approach and simple mathematical techniques including percentages and mean.

The total number of failures (TNF) per component was obtained by summing the seasonal failures and annual failures of the machine component and calculated using the following equation:

$$\mathrm{TNF(per\ component)} = \sum_{i=1}^{n}(\mathrm{SF}_i + \mathrm{AF}_i),$$

where TNF is the total number of failures per component, SF is seasonal failures, AF is annual failures, n = component number, and i = 1, 2, 3…n.

Furthermore, the total component failures (TCF) per machine were the TNF for each type of machine component and computed as follows:

$$\mathrm{TCF(per\ machine)} = \sum_{i=1}^{n}\mathrm{TNF}_i,$$

where TCF is the total component failures per machine, TNF is the total number of failures for each type of machine component, n is the number of components, and i is 1, 2, 3…n.

3 Results and discussion

3.1 Type and number of farm machinery

Five types of farm machines were identified and consisted of mouldboard plows, rotary tillers, four-wheel tractors, transplanters, and combine harvesters. They are managed by farmer groups from three regions of survey locations, namely 14 groups from Kampar, 11 groups from Indragiri Hulu, and 8 groups from Siak. The groups are still running actively to offer services for group members (farmers) and other farmers. These farmer groups are given the name “Farm Machinery Hire Services”, which manage farm machines aided by the Government [42]. They offer services for performing rice farming operations, such as tillage, transplanting, and harvesting/threshing, depending on the type of machines owned. Each farmer group has a coverage area owned by group members. The number of farm machines suffering failures from five types and coverage areas for each regency are presented in Table 1.

According to Table 1, the number of farmer groups consisted of 14 in Kampar, 11 in Siak, and 8 in Indragiri Hulu with coverage areas of 1,126, 1,446, and 2,222 ha, respectively. Both mouldboard plows and rotary tillers are dominantly owned and used by farmer groups, followed by rice transplanters, combine harvesters, and four-wheel tractors. The coverage areas that were able to be worked with available farm machines were only 20% in Kampar, 31% in Indragiri Hulu, and 35% in Siak from the total area of paddy fields in each regency. It means the availability of four-wheel tractors to replace both types of small machines is still limited. Both mouldboard plows and rotary tillers are still dominant used by farmers for tilling rice fields because of suitable for the small farm scale.

The largest number of farm machines owned by farmer groups in each survey location were mouldboard plows followed by rotary tillers. While the other types of machines varied in number and the number was not more than 12 units. However, the number of farm machines managed by the group was not sufficient to work each type of farming operation with the total coverage areas owned by the group members. Indeed, the cases of limited availability of machinery are commonly found in farming practices [43]. The limited number of farm tractors available leads to heavy use (overload) of the machine every growing season. Consequently, farm tractors that operated in

Table 1: Type and number of investigated farm machines, farm machine failure, coverage area, and paddy filed area

Regency/survey location	No. of farmer groups	Type of farm machines	No. of investigated farm machines	No. of farm machine failure	Total coverage area (ha)	Total paddy field area (ha)
Kampar	14	Mouldboard plow	39	25	1,126 (20%)	5,507
		Rotary tiller	20	12		
		Four-wheel tractor	10	7		
		Rice transplanter	12	8		
		Combine harvester	11	8		
Indragiri Hulu	11	Mouldboard plow	28	23	1,446 (31%)	4,643
		Rotary tiller	18	15		
		Four-wheel tractor	6	4		
		Rice transplanter	9	6		
		Combine harvester	7	5		
Siak	8	Mouldboard plow	24	20	2,222 (35%)	6,273
		Rotary tiller	16	12		
		Four-wheel tractor	8	4		
		Rice transplanter	9	6		
		Combine harvester	7	5		

overcapacity each season triggered the machine to suffer failures earlier (premature) and more frequently.

In addition, it was found that most of the investigated farm machines suffered component failures for more than 50% in general (Figure 2). The failure percentage of the failures also varied among machine types and regencies which were caused by different farm machinery management practices and operational conditions of farm machines. The mouldbard flows experienced the highest failure rate in each location followed by rotary tillers.

3.2 Component type and failure frequency

The component types and failure frequencies were exhaustively investigated from five selected farm machines including mouldbard plows, rotary tillers, four-wheel tractors, tranplanters, and combine harvesters. These machines are used every season to carry out fieldwork following the rice cultivation system, namely in the wet and dry growing seasons. The working time of using the machine is approximately one month per season according to the type of rice

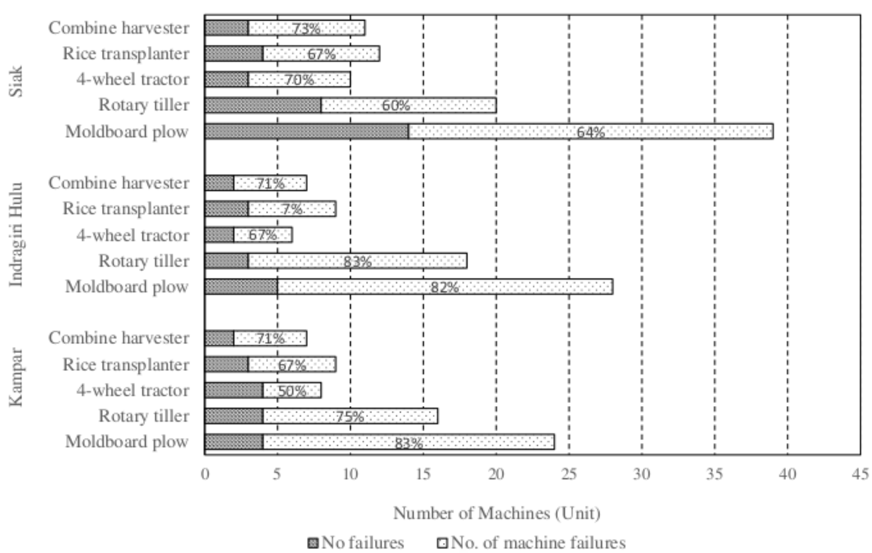

Figure 2: Number of machines suffered failures with different types and locations.

growing pattern. Working area per season ranged from 10 to 12 ha for mouldbard plow, from 12 to 16 ha for the rotary tiller, from 25 to 38 ha for 4-wheel tractor, from 25 to 30 ha for rice transplanter, and from 25 to 38 ha for combine harvester. The machines worked very intensively to complete operations for all the rice fields in the areas owned by the group members. However, the area could not be fully worked due to the limited amount of available farm machinery. The rest of the area is usually taken up by individual farmers who provide the same hiring service. Another choice for farmers use the hoe to till the land, especially for the smaller-scale rice farms.

The component failure frequency was categorized into seasonal failures and annual failures. Cases of component failure were found for each type of machinery with a different component suffering failure, as shown in Table 2. Seasonal failures were the component that has failed each season, while annual failures have failed annually. Mouldboard plows had the most component failures to reach 137 cases, followed by rotary tillers with 85 cases and four-wheel tractors with 57 cases. Rice transplanters and combine harvesters were found in 34 and 43 cases, respectively.

The result indicated that the failure frequency for the same machine component was different. These differences may be caused by different field conditions, maintenance and storage facilities, qualified operators, and heavy (overloading) use of the machines. Fuel, oil and air filters usually fail or are replaced on a seasonal basis, while few fail each year. In contrast, most components suffered annual failure, such as rotary blades, mouldboard blades, wheel seals, wheel axles, rotary chains, etc. Additionally, some components failed each year, such as clutches, gears, gaskets, and bearings. However, field conditions and heavy use (overload) of machinery were the main causes of more rapid failures (premature failure) for these components.

Figure 3 shows machine component failures that happened seasonally as well as annually during field operations. Three types of farm machines, including mouldboard flows, rotary tillers, and rice transplanters, suffered the most component failures in season, accounting for 59, 69, and 53%, respectively. Both four-wheel tractors and combine harvesters suffered the most component failures annually, accounting for 53 and 56%, respectively. According to the interview with the operators, the component failures that occurred in the season annoyed and caused field stoppage during operation. The failures of combined harvester components, for example, can delay the harvesting operation and, in turn, cause yield losses. The high frequency of machine component failures sometimes made farmers reluctant to purchase and use farm machines. They later seek another option of manual tools to perform the farming operation, such as a hoe for tilling soil, a sickle for harvesting rice, and a power thresher for threshing rice.

3.3 Root cause of the component failures

The root cause of machine component failures was identified to determine the primary source of the failures. According to interviews with operators and mechanics, the failures of the machine components were caused by a variety of sources, as shown in Table 3. It was found that five root causes of component failures were identified during the interview and investigation, consisting of poor field conditions, ignoring maintenance, unkilled operators, improper storage, and heavy machine operation.

The root cause for each failure can be explained as follows:

a. Poor field conditions

A field condition is a circumstance found in an area of a rice field that could not be foreseen in advance as a cause of machine component failures. A rice field is a flooded field of arable land used for growing crops, especially rice. Abundant weeds, lack of water, remaining small stumps, rocks, other plant residues, and bad farm roads are evidence of poor field conditions (Figure 5). We found that the machine components suffered from poor field conditions, such as the moldboard blade, rotary blade, disk blade, wheel bearing, wheel axle, and others. Many components, such as plows, rotary plows, and so on, have not done a good job due to parts being worn out. They must be repaired or replaced immediately if necessary for the component to function correctly. Poor field conditions mostly contributed to machine component failures accounting for 108 (30%) cases (Table 3 and Figure 4).

b. Ignoring maintenance

Maintenance is essential to keep machines in good working condition according to their intended application so that they cannot be ignored. By neglecting maintenance tasks, machines will fail faster. Routine maintenance refers to maintenance activities performed on a regular schedule, such as inspecting or maintaining machinery. Routine maintenance is also a key element of preventive maintenance, reducing the possibility of unexpected component failures. Without routine maintenance, farm machinery will perform less efficiently and will be immobilized longer during operation. Keeping machinery clean is another essential aspect of maintenance, and clean machinery will operate better. Three important maintenance tasks were often

Table 2: Working area and component failure frequencies for selected farm machinery

Type machines	**Working area per unit per season (ha)**	**Type of component failure**	**Failure frequency**		**Total number of failure cases**
			Seasonal failures	**Annual failures**	
Moldboard plow	10–12 ha (2–2.5 days/ha)	Fuel filter	18	3	21
		Oil filter	17	2	19
		Air filter	9	8	17
		Mouldboard plow	7	10	17
		Puddler/leveller	8	5	12
		Wheel axle	7	8	15
		Belting	8	8	16
		Wheel seal	7	5	12
		Clutch	—	8	8
		Bearing	—	7	7
Total cases			**81**	**56**	**137**
Rotary tiller	12–16 ha (1.5–2 days/ha)	Fuel filter	15	3	18
		Oil filters	15	2	17
		Rotary blade	9	—	9
		Wheel axle	6	4	10
		Gear transmission	0	7	7
		Clutch Facing	0	7	7
		Wheel seal	5	3	8
Total cases			**59**	**26**	**85**
Four-wheel tractor	25–38 ha (1–1.5 ha/day)	Rotary blade	7	3	10
		Disk plow blade	7	1	8
		Air filter	9	—	9
		Front-wheel axle	1	8	9
		Rotary chain	1	7	8
		Front wheel bearing	2	6	8
		Seal front wheel	—	6	6
Total cases			**27**	**31**	**57**
Rice transplanter	25–30 ha (1–1.2 ha/day)	Fuel filter	8	—	8
		Oil filter	9	—	9
		Transplanter claw	1	7	8
		Gear	—	5	5
		Wheel axle	—	4	4
Total cases			**18**	**16**	**34**
Combine harvester	25–38 ha (1–1.5 ha/day)	Fuel filter	9	1	10
		Oil filter	9	—	9
		Track roller bearing	1	8	9
		Rubber track	—	8	8
		Belting roll	—	7	7
Total cases			**19**	**24**	**43**

ignored by operators in survey areas, i.e. not performing routine maintenance, not cleaning the machine before storing it inside, and not replacing immediately worn parts. This ignoring maintenance caused machine component failures in 76 cases or 22% of the total failures (Table 3 and Figure 4).

c. Unskilled operator

It is essential for machinery operators to have good skills and be able to operate the machine safely and efficiently. This includes knowing how to start, drive, and operate the machine, maintain and repair it, and control its functions. Maintaining the machines in good condition allows the operator to reduce the risk of failures occurring in the operations. Machine maintenance skills are also essential for machine operators to understand how the machine works and what parts need to be serviced. In the survey area, machine operators had three disadvantages, which are lack of training,

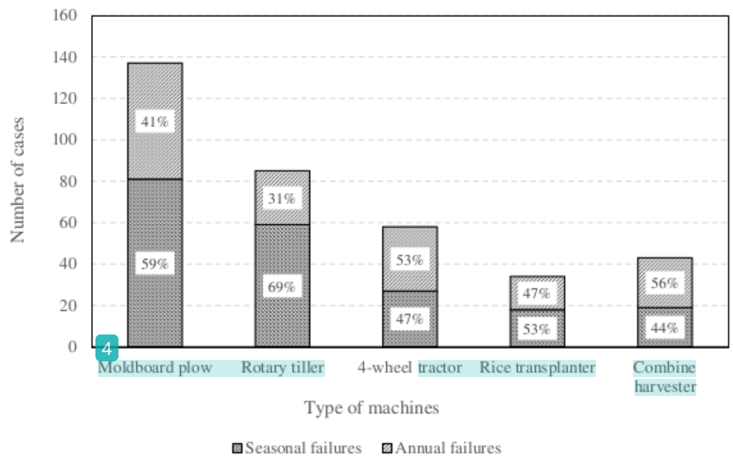

Figure 3: Seasonal and annual failures of machine components.

Table 3: Root causes of failure for machinery components

No	The root cause of component failures	Number of cases	Description
1	Poor field conditions	108	– Heavy weed growth in paddy field – Lack of supplying water (dry season) – Remaining small stumps and stones on field – Poor farm road
2	Ignoring maintenance	76	– Not performing routine maintenance – Not cleaning machine after use – Not replacing immediately worn parts
3	Unskilled operator	47	– Untrained operators – Inexperienced operators – Operator carelessness
4	Improper storage	51	– Store machine outside without protection – Inadequate machinery storage facility
5	Intensive machine use (overload)	74	– Overworking machines – Excessive speed operation

inexperience, and carelessness. This deficiency can lead to accidents and ultimately failure of machine parts when operators are performing their jobs. It was found that 47 cases (13%) of component failures were caused by unskilled machine operators (Table 3 and Figure 4).

d. Improper storage

Farm machinery must be stored in a storage shed, especially after use during seasons, to protect it from bad weather conditions. By keeping the machines in the storage shed, it can avoid damage from weather, dust, dirt, and grime, and even avoid costly repairs and potential delays. The storage shed must be large enough to keep farm machinery safe and have enough space for

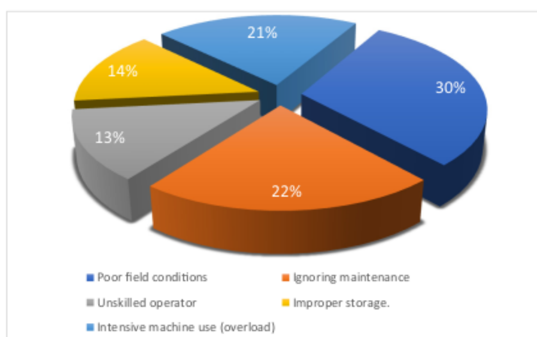

Figure 4: Root cause contribution toward total component failures.

Figure 5: Wetland rice field, farm road, and dryland field in survey areas. Source: Photo taken by the authors.

storage for repairs and maintenance. The result of the survey showed that most of the farmers put their farm machines outside without protection and with insufficient storage facilities to ensure the safety of the machinery. The condition of the storage shed of farm machinery located in the research area is shown in Figure 6. The result of field surveys showed that 51 (14%) cases of component failure were caused by improper storage (Table 3 and Figure 4).

e. Heavy machine use (overload)

The limited farm machinery available on the farm caused the machines to be overloaded to achieve the target of the operation. Interviews with machine operators revealed that the lack of farm machine numbers on the farm made a difficult to reach the target operation every season, although the machine worked over capacity. Such condition makes machine components/parts to prone failure. The heavy use of the machine caused some machine components such as wheel bearings, seals, axles, and others to suffer failures. The number of component failures caused by heavy machine use was found to be 74 cases or 21% of the total cases (Table 3 and Figure 4).

3.4 Improvement measures to prevent component failures

As previously mentioned, machinery failures can be extremely costly and lost work time to make repairs and maintenance. Hence, the above failures of machine components/parts must be prevented by the following measures:

1. The rice cultivation area must be cleaned before starting operation, keeping all materials and weeds such as weeds, stumps, stones, and other plant residues away from the working area. In the dry season, supplying enough water into the field to facilitate tillage operation. The farm road must be constructed better to avoid accidents when machines pass along the road.
2. Farm machinery must be regularly maintained with certain activities such as inspection, regular replacement, cleaning, washing, lubrication/greasing of moving parts, and periodic maintenance checks. For example, if a machine component breaks, it must be replaced immediately, and other components that may have caused the original failure must be checked or replaced. If the broken components are just replaced, this is a temporary solution and may return with the same problem.

Figure 6: Farm machines stored outside during the off-season. Source: Photo taken by the authors.

3. Machine maintenance is based on keeping the machines in the storage shed. The machine must be stored inside. All electrical connections and other areas cleaned of dust and dirt during use in wet and muddy conditions before parking in storage sheds. The storage is also useful to prevent mice and rats from getting into machinery and other animals.
4. Machine operators must have adequate training/experience in the safe operation of farm machinery. It must ensure that machine operators receive adequate training to help minimize breakdowns due to operator error/mistake. The training includes improving the use of machines, the ability of the operators to recognize the risks associated with machines, and reducing the loss of working time and damages due to inappropriate use of farm machines. In addition, money and time invested in training can extend the life of farm machinery.
5. Intensive use (overload), which forces machines to work as efficiently as possible, can stress and cause premature failure of some parts. Pushing machines too hard for too long and forcing them to do things they weren't designed to do can cause components to fail faster. Operators are therefore advised to operate the machines exactly at their intended maximum capacity to avoid unnecessary stress and premature failure as a result of overload.

4 Conclusions and recommendations

Farm machines are mostly managed by farmer groups, and the method is most popular among small rice farmers who directly receive farm machinery from government aid. Five types of agricultural machinery were investigated, including mouldboard plows, rotary tillers, four-wheel tractors, rice transplanters, and combine harvesters. They were found high frequency of breaking down due to the failure of one or more components/parts. Mouldboard plows had the most component failures to reach 137 cases, followed by rotary tillers with 85 cases and four-wheel tractors with 57 cases. While rice transplanters and combined harvesters were found to have 34 and 43 cases, respectively. Thirty percent of component failures were found to be mostly caused by excessive weed growth, inadequate water supply, small stumps and stones, and poor farm roads. About 22% of component failures were caused by ignoring maintenance, which includes not doing routine maintenance, cleaning the machine after use, and replacing worn parts right away, and then, approximately 21% of component failures were attributed to the intensive use of machines, including overworking the machines and operating them at excessive speeds. Moreover, improper storage practices (such as storing machines outdoors without protection and inadequate machinery storage facilities) and unskilled operators (such as untrained, inexperienced, and reckless operators) were responsible for 14 and 13% of component failures, respectively.

Based on the results of these field investigations, the following recommendations are given to prevent machine component/part failure:

1. Machine operators must keep all materials and crops – such as weeds, stumps, rocks, and other plant residues – away from work areas before beginning cultivation or operation.
2. Owners and operators of machinery are required to conduct regular maintenance, which includes inspecting the machine on a regular basis, checking, cleaning, and lubricating the moving parts.
3. Farm machinery needs to be stored inside and kept clean and out of the dust and filth before parking in the storage shed.
4. Machine operators need to have the necessary training and experience to help reduce failures brought on by operator error or mistake.
5. Machine operators must run their machines precisely at the maximum power levels that are designed for them to prevent needless strain and early failure.

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Khairizal, SS; data curation, Khairizal; writing-original draft preparation, UP; writing-review and editing, UP; visualisation, Khairizal, SS; supervision, UP, Khairizal; project administration, SS; funding acquisition, SS.

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Data availability statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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