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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Assessment of rice farmers' knowledge and perception of harvest and postharvest losses in Ghana

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Abstract: Farmers' knowledge and perception of harvest and postharvest losses in rice production across three agro-ecological zones of Ghana were examined using farm-level data collected from 108 randomly selected rice farmers. To examine the perception and knowledge of farmers on harvest and postharvest losses, means of a 5-point Likert scale were estimated compared with the values of the individual perception statements. Results indicated that rice production was male-dominated (80%) with an ageing farmer population (42 years on average), smaller farm sizes (~5 acres) with over 70% of farmers formally educated. This suggests the potential and need for mechanised interventions in rice production. Majority of the farmers sampled (over 95%) had experienced and were aware of harvest and postharvest losses in rice. Whereas over 50% of the farmers were cultivating the Jasmine rice variety, it was perceived by over 65% of the farmers to be associated with higher harvesting losses. Mechanical agents such as lack of appropriate harvesting machinery were perceived by over 40% of the farmers to cause harvesting losses. On the method of rice threshing, over 50% of the farmers used combines, 36% used the threshing by impact "bambam" method, 11% bag beating and 2% used mechanical threshers. Rice harvest and



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Shadrack Kwadwo Amponsah holds both PhD and Master's degree in Agricultural Machinery Engineering and a Bachelor's degree in Agricultural Engineering from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, in Ghana. He currently works with the Crops Research Institute under the Council for Scientific and Industrial Research (CSIR), Ghana, as a research scientist. His research interests include machine design and fabrication, integrated agriculture, conservation agriculture, performance evaluation of agricultural machinery and postharvest engineering, among others. The team of researchers who contributed to this work as authors include socio-economists, agricultural engineers and postharvest experts. As part of Dr. Amponsah's PhD studies, he worked with a multidisciplinary team of researchers in identifying the causes and extent of rice harvest and postharvest losses in Ghana and to suggest sustainable ways of arresting this worrying situation, which led to the birth of this article.

PUBLIC INTEREST STATEMENT

Rice harvest and postharvest losses could greatly affect sustainable food security globally. Farmers' knowledge and perception of rice harvest and postharvest losses across three agro-ecological zones of Ghana were examined by interviewing 108 randomly selected rice farmers. From the study, it was noted that majority of the farmers sampled (95%) had experienced and were aware of harvest and postharvest losses in rice. The lack of appropriate harvesting machinery was perceived by over 40% of the farmers to cause harvesting losses. Farmers accepted the fact that traditional rice harvest and postharvest methods tend to increase losses and that it was at the harvesting and threshing stages that losses were predominant. The study results suggest that well-targeted efforts to reducing harvest and postharvest losses may interest farmers and lead to the adoption of demand-driven appropriate technologies and best agronomic practices for increased rice production nationwide.

postharvest activities constituted 21% of total production cost, while accounting for nearly 20% of total grain loss. It is recommended that aside the mechanised interventions, efforts should be geared towards proper development of rice fields to ensure sustainable production and improved land productivity.

Subjects: Environment & Agriculture; Food Science & Technology; Engineering & Technology

Keywords: paddy; perception; knowledge; farmers; harvest; postharvest; losses

1. Introduction

Rice is the staple food for over three billion people, constituting more than half of the world's population and supplying 20% of the calories consumed worldwide (Kubo & Purevdorj, 2004; Saed et al., 2011). The importance of rice to the Ghanaian economy cannot be overemphasised, accounting for nearly 15% of the gross domestic product (ISSER, 2000). The crop has become the second most important food staple after maize in Ghana and its consumption keeps increasing as a result of population growth, urbanisation and change in consumer habit (MoFA, 2009). Rice also constitutes 58% of all cereal imports in Ghana (CARD, 2010). In addition to being a staple food mainly for high-income urban populations, rice is also an important cash crop in the communities in which it is produced (Angelucci, Asante-Poku, & Anaadumba, 2013). Between 2005 and 2010, Ghana ranked among the top 50 rice producers worldwide (FAOSTAT, 2013).

The goal of proper harvesting is to maximise grain yield while minimising grain losses and quality deterioration (IRRI, 2015). However, improper harvesting and threshing, according to IDRC (1976), could result in losses of up to 5% of the crop. These losses could even go up to 10% in some cases (Hodges & Maritime, 2012). Harris and Lindblad (1978) attributed the losses which occur at each stage of the rice value chain to a group of general level factors which were; socio-economic, biological, chemical, mechanical and environmental. A study by Global Strategy (2015) cited that environmental agents of harvest and postharvest losses include insects, vermin, moulds, temperature, weather conditions and humidity while socio-economic factors include lack of access to market information, lack of access to financial support and pilferage, among others. Mechanical causes of losses include factors such as lack of or inappropriate machinery, poor efficiency of existing machinery and spillage. Biological causative agents of losses include factors that relate to the grain properties such as shatterability and yield. Chemical factors of harvest and postharvest losses include the use of plant protection agro-inputs. A given combination of any number of these factors may be at work at any given time to influence losses (Lantin, 1999). Identifying the causes of rice harvest and postharvest losses is as crucial as the solution required.

Buri, Imoro, and Ahiakpa (2011) mentioned that Ghana's mean rice yield is 2.4 t/ha as against an achievable yield of 6.5 t/ha. Aside the need for improved methods of cultivation and high-yielding varieties, harvest and postharvest losses could be reasons for the low rice yields. Other reasons for the high levels of harvest and postharvest losses could be that either farmers fail to recognise these losses as significant enough or have no appropriate alternative to curb the situation and therefore tend to ignore. Mechanisation of rice harvesting has been identified as the most promising area for intervention and for realising the potential of this crop (Rickman, Moreira, Gummert, & Wopereis, 2013). Currently, there is a dearth of research information on the level of rice harvesting mechanisation options available to smallholder rice farmers in Ghana.

Information on farmer's knowledge and perception of harvest and postharvest losses is essential in identifying where mechanised interventions to arrest these losses may be required. It will also guide other relevant stakeholders like the government, the private sector and engineers on the type of mechanised intervention to provide to these farmers in the quest to maximise efficiency of work and increase production.

2. Objectives of the study

The main objective of this study was to assess rice farmers' perception and knowledge of harvest and postharvest losses in selected rice growing areas of Ghana. Specifically, the study sought to:

- (1) identify the stages in rice production where losses occur, the causes and the extent of these losses.
- (2) ascertain the level of adoption of rice harvesting mechanisation in selected rice-growing areas of Ghana.
- (3) identify critical areas in the rice production value chain that require government and private stakeholder support.

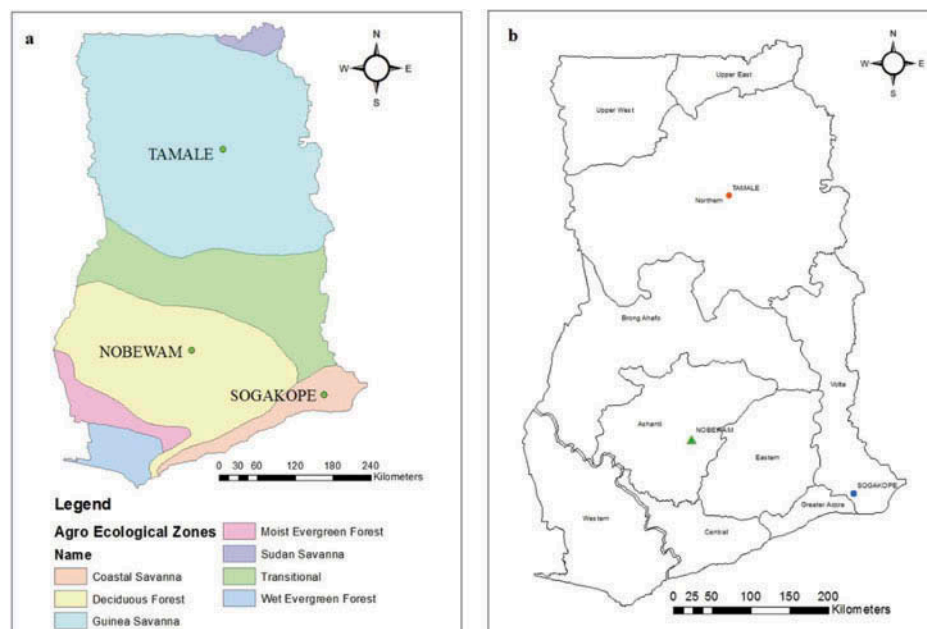
3. Methodology

3.1. Study area

The study was conducted in the coastal savannah, forest and guinea savannah agro-ecological zones of Ghana. From each zone, three communities were randomly selected from a list of major rice-producing communities. The selected communities were Nobewam from the forest, Sogakope from the coastal and Tamale from the guinea savannah agro-ecological zones (Figure 1). Study locations were each described based on information from the Ghana Statistical Service (2014) for the respective districts: Ejisu-Juaben, South Tongu and Tamale.

Nobewam, located in the Ejisu-Juaben municipality in the Ashanti region of Ghana, experiences tropical rainfall that is bi-modal rainfall pattern and wet semi-equatorial climate. Major raining season (1,200–1,500 mm per year) from March to July and minor (900–1,120 mm per year) begins in September and ends in November. The mean annual rainfall is 1200 and temperatures range between 25°C in August and 32°C in March. Relative humidity is fairly moderate but quite high during rainy seasons and early mornings. The distribution of temperature and rainfall patterns in the area enhances the cultivation of many food and cash crops with rice being the major in the town. Nobewam is located within the semi-deciduous forest zone, with forest degradation to secondary forest due to unfriendly farming practices, stone quarrying activities and illegal chain

Figure 1. (a) Agro-ecological map. (b) Regional map of Ghana showing study locations.



saw operations in the municipality. The flora and fauna is diverse and composed of different species of both economic and ornamental tree species with varying heights and game and wildlife. The topography of the area is generally undulating, dissected by plains and slopes with heights ranging between 240 and 300 m above sea level. The geology of the area is Precambrian rocks of the Birimian and Tarkwaian formations that are generally suitable for agriculture. The soils include the associations of the Kumasi-Offin, Bomso-Offin, Kobeda-Esshiem-Oda, Bekwai-Oda and Juaso-Mawso compounds. The geology and soils types in the municipality offer vast opportunity for the cultivation of traditional and non-traditional cash crops and other staple food stuff and thus present the municipality as one of food basket case in Ghana. The Oda, Anum, Bankro, Hwere and Baffoe Rivers are the major rivers in the area. These rivers flow continually throughout the year and it is used for both domestic and agricultural purposes. An example is the Anum River Valley used for irrigated rice production at Nobewam.

Sogakope is located in the South Tongu District in the Volta Region of Ghana. It is endowed with large clay deposits which are predicted by geologists to last for over 100 years if it is mined commercially and in a sustainable way. The district lies within the Wet Semi-Equatorial and Dry Equatorial Climate Zones. The northern part of the district lies within the Wet Semi-Equatorial Zone while the southern part is in the Dry Equatorial Climatic Zone. The climate of the district is also influenced by the Southwest Monsoon Winds twice in a year resulting in a double maxima rainfall regime. The major rainy season is from late March or early April to July with the peak in May and June (peak average of 195 mm). The minor season is from September to November with peak average rainfall of 73 mm. The driest month of the year is August with a temperature between 22.6°C and 29.3°C. Sogakope is located in the coastal savannah agro-ecological zone and covered with swamps and mangroves. The savannah vegetation supports the production of livestock and the swampy areas favour the cultivation of rice, okra, pepper and sugar cane.

Tamale, the capital of the Tamale Metropolis, receives only one rainfall (mono modal) season in a year and this has affected effective agricultural production in the area. It starts in either later March or in early April and ends in October. Rainfall ranges between 60 and 240 mm and peaks in September (240–250 mm). Daily temperature in the Metropolis varies from season to season, ranging between 25°C and 39°C annually. During the rainy season, residents experience high humidity, slight sunshine with heavy thunder storms, compared to the dry season which is characterised by dry Harmattan winds from November to February and high sunshine from March to May. The Metropolis lies within the savannah woodland zone of the country. The trees in this zone are short scattered wood lots in nature. Major tree types in the Metropolis are Dawadawa, Nim, Acacia, Mahogany and Baobab, among others. The Metropolis is endowed with naturally grown tall grasses during the rainy season which are used to make the local mats popularly called “Zana mat”. Besides, the only economic tree is the Shea tree which has gained international recognition in the cosmetic industry. The main soil types in the Metropolis are sandstone, gravel, mudstone and shale that have weathered into different soil grades. Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay and laterite ochrosols.

3.2. Sampling and data collection

From each of the three study location, 36 rice farmers were randomly selected. Totally 108 rice farmers were involved in the study. Sample size selection was based on recommendation by Harris and Lindblad (1978) assuming 60% and 20% expected highest and lowest loss, respectively, at a precision of $\pm 5\%$. Both formal and informal approaches were used in collecting the data. First participatory rapid appraisal techniques such as the focus group discussions were used to collect information about the communities as well as general information about the community with regard to rice production. This provided useful information for improving the formal data collection. Following this approach, the formal survey data was collected using semi-structured questionnaires through individual interviews. The information gathered includes data on personal information, rice production, harvesting and postharvest management, perceived grain losses

and yield. Data on total cost of rice production per acre was also collected from farmers with particular attention to the cost of each production activity at the various study locations.

3.3. Methods of analysis

The data used for this study were analysed using the STATA 14 statistical software package (StataCorp, 2015). Descriptive statistics were used to summarise the data. Farmers' perceptions of harvest and postharvest losses were examined by adopting a 5-point Likert scale (Likert, 1932) using the following perception indices: 1 = strongly disagree, 2 = disagree, 3 = indifferent, 4 = agree and 5 = strongly agree. Consequently, the mean and corresponding standard deviation for each harvest and postharvest statement were determined using Equations 1 and 2, respectively.

$$\bar{x} = \frac{\sum x_i}{N} \tag{1}$$

$$SD = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N - 1}} \tag{2}$$

where,

x_i = number of individuals who chose the i th response.

N = total number of respondents.

For the Likert scale, a mean of 4 or more denotes agreement whereas 2 and below implies disagreement.

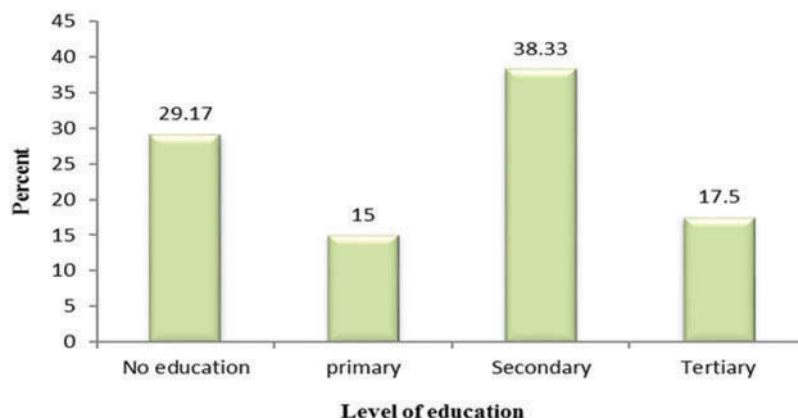
4. Results and discussion

4.1. Level of education of farmers

The levels of education of farmers are presented in Figure 2. In all, secondary education recorded the highest percentage (38.33%), whereas 29.17% of them had no formal education with the remaining having either primary or tertiary education.

However, comparing the percentage that had no formal education to those with some level of formal education, the result indicates that over 70% of the farmers were educated. Farmers with some level of formal education may better understand the benefits of improved harvest and postharvest technologies than those with no formal education. Thus, there is the potential for enhanced adoption of improved storage, harvesting and postharvest technologies among rice farmers.

Figure 2. Level of education of respondents.



4.2. Experience in rice cultivation

The experience in rice cultivation was categorised into groups and the distributions presented in Figure 3. In general, only about 27% of the farmers had 20 years and above experience in rice production, with the majority of them having less than 20 years of experience in rice production.

This suggests that relatively farmers are generally less experienced in the cultivation of rice; hence, there is the potential to enhance the production of the crop and increase farmer productivity by increasing access to improved technologies including harvest and postharvest technologies.

4.3. Other household characteristics

Other household characteristics of the rice farmers are presented in Table 1. The average age of the sampled rice farmers was 42 years. A typical rice producing household consisted of about 7 members with over 80% of them being males.

Sample rice farmers cultivated an average of about 5 acres. These factors indicate that generally, rice production in the sample areas was male-dominated and this is consistent with other studies in rice production across the country (Asante et al., 2013; Diako, Sakyi-Dawson, Bediako-Amoa, Saalia, & Manful, 2010). The inherently high labour requirement in rice cultivation could have possibly accounted for this.

4.4. Rice production characteristics

The varieties cultivated and their respective perception on levels of harvest and postharvest losses are presented in Table 2. The result shows that the most common rice variety cultivated among the farmers was Jasmine with 57% of the farmers cultivating it.

Figure 3. Experience in rice cultivation.

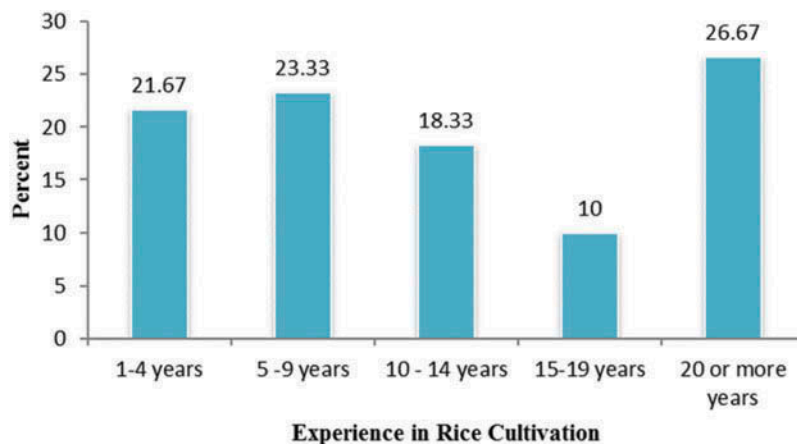


Table 1. Other household characteristics

Variable	Mean	SD
Age	41.5	12.4
Household size	7.0	3.1
Farm size	5.0	2.1
Gender	0.8	0.4

Table 2. Rice variety cultivated and the perception on levels of harvest and postharvest losses

	Cultivated (%)	Perception on loss (%)
Jasmine	57.40	65.74
AGRA	37.03	30.56
Digang	1.85	0
Amankwatia	1.86	1.85
Togo marshal	1.86	1.85

This was followed by AGRA cultivated by 37% of the farmers. Conversely, other varieties such as Digang, Amankwatia and Togo marshal were the least cultivated among the sampled rice farmers. Information provided by farmers on the high percentage of Jasmine and AGRA cultivation revealed that the seed inputs were provided through rice out-grower schemes and therefore farmers had less say in the type of variety to cultivate. Furthermore, Jasmine and AGRA were perceived as the varieties with the highest level of harvest and postharvest losses than any other rice variety which was attributed to their higher grain shatterability. Though farmers perceived lower harvest and postharvest losses with Amankwatia and Togo marshall varieties due to their inherently lower grain shatterability, they claimed these varieties were not readily available on the market. Thus, efforts should be geared towards making seeds accessible to farmers to ensure increased production and reduced grain postharvest losses.

4.5. The use of harvest and postharvest machinery

Figure 4 presents result of the distribution of farmers’ usage of harvest and postharvest machinery. Overall, 67.5% of the farmers were using harvest machinery while almost all the farmers were using some forms of postharvest equipment. This indicates that, in general, rice farmers make the efforts to obtain good quality grains by investing and using appropriate harvest machinery and postharvest equipment.

4.6. Awareness and experience of harvest and postharvest losses in rice

The results of the awareness and experience of harvest and postharvest losses among farmers are presented in Figure 5. The result depicts that almost all the farmers (98%) were fully aware of harvest and postharvest losses whereas about 96% and 98% had experienced harvest and postharvest losses on their rice fields, respectively. This suggests that these farmers will be more willing to accept improved techniques for reducing these postharvest losses.

Figure 4. Use of harvest and postharvest machinery.

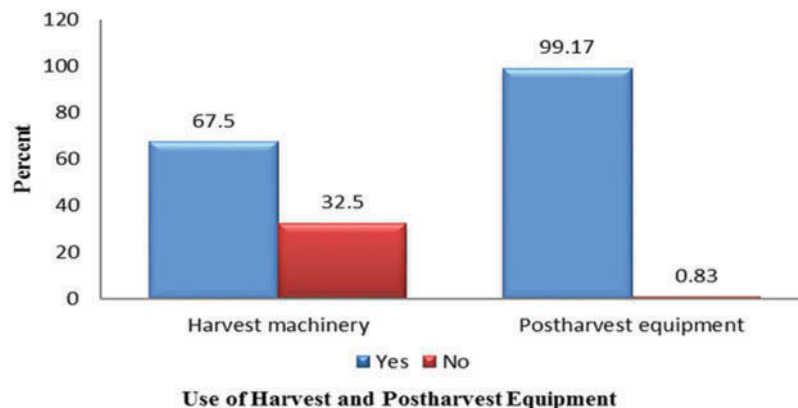
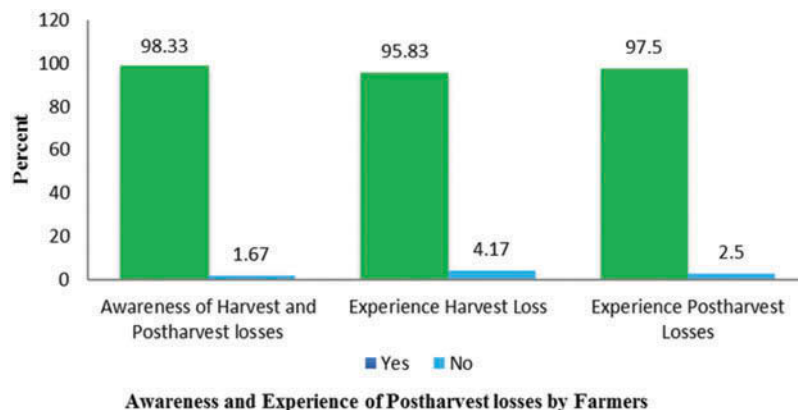


Figure 5. Farmer awareness and experience of postharvest losses.



4.7. Causes of postharvest losses in rice

Farmers’ perception of the causes of postharvest losses among farmers is presented in Table 3. The most common causes of harvest losses among rice farmers were mechanical and environmental factors accounting for about 44% and 23% of respondents, respectively. However, in terms of postharvest losses, mechanical and socio-economic factors were prominent consisting about of 43% and 37%, respectively.

Farmers cited lack of appropriate harvest and postharvest technologies under the mechanical factors and labour shortage as the socio-economic factor for the harvest and postharvest losses perceived. Again, farmers attributed environmental factors mostly to insect attacks and harsh weather conditions that causes crop lodging and grain shattering. This suggests that in designing postharvest technologies, it is essential to take these factors into consideration.

4.8. Methods used for rice threshing

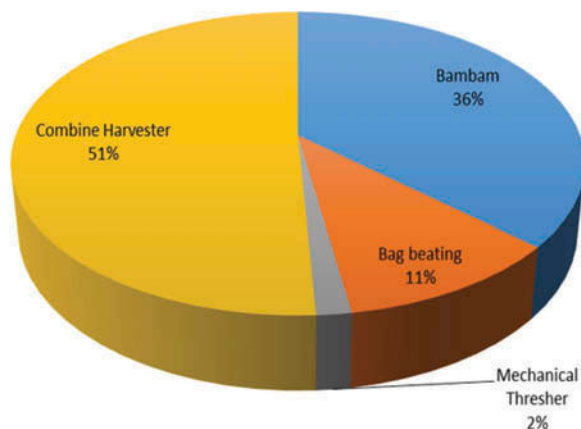
Figure 6 illustrates the common methods used in threshing of rice by sample farmers in the study area. Combine harvester was the commonly used method for threshing rice and was used by about 51% of the farmers followed by bambam (threshing by impact method) which was used by about 36% of the farmers.

Others include bag beating (11%) and mechanical thresher which accounted for only 2% of the sampled farmers. The significantly high level of combine use from the survey results was attributed to the activity of some private rice out-grower scheme companies located in the Northern and Volta regions. These companies provide agricultural support services, including mechanisation, to these smallholder farmers who are members of their out-grower scheme in exchange for paddy under a mutually beneficial contractual agreement (Paglietti & Sabrie, 2012; Technoserve & IFAD, 2011). This suggests that these private partners are doing a good job in the provision of rice mechanisation for improved production and more of such efforts should be encouraged. However,

Table 3. Perception on causes of harvest and postharvest losses among farmers

Causes	Harvest loss (%)	Postharvest loss (%)
Socio-economic	22.22	37.07
Biological	10.26	10.18
Chemical	0.85	0
Mechanical	43.59	43.50
Environmental	23.08	9.25

Figure 6. Methods used for rice threshing.



given that combine harvesters may be costly and unaffordable to the farmers, designing appropriate mobile and affordable small threshers could help in reducing postharvest losses during threshing.

4.9. Perception of losses experienced by farmers during harvest and postharvest activities

The perception of losses experienced by farmers during harvest and postharvest stages of production is presented in Table 4.

More than half of the farmers (53.70%) perceived to have experienced up to about 9% losses during the harvest stage while over 60% experienced similar percent losses during postharvest activities. The next highest percentage loss after this was between 10% and 19% which constituted about 36% of the sample farmers during the harvesting stage while about 31% of them experienced losses during the postharvest activities. The result depicts that although rice losses of up to 9% of total production was predominant, it was more conspicuous during the postharvest stage than at the harvesting stage.

4.10. Harvesting, drying and milling methods

The harvesting, drying and milling methods used in rice production are presented in Table 5.

Result shows that the sickle and panicle are the predominant techniques used in manual rice harvesting though sickle method was most preferred with over 50% of sampled farmers using it. Tarpaulin or plastic sheets was the commonly used method for drying paddy with over 50% of farmers adopting it while the remaining farmers dried their paddy on cemented platforms. Most farmers stored their paddy for a period of between 3 and 6 months before milling. This was practised by 63.88% of the farmers. The mechanical huller was the most widely adopted milling method with over 80% of farmers using it. The common type of mechanical huller used was the Engelberg type with steel rollers.

Table 4. Farmer perception of losses experienced at harvest and postharvest stages		
Category of loss (%)	Harvest stage (%)	Postharvest stage (%)
0-9	53.70	62.03
10-19	36.11	31.48
20-29	10.19	5.56
30-39	0	0.93

Table 5. Harvesting, drying and milling methods

Item	Percent	Item	Percent
Method of harvesting		Paddy milling method	
Panicle	48.15	Hand pounding	12.03
Sickle	51.85	Saddle stone	0.93
Method of drying		Mechanical huller	
Cemented platform	48.15		87.04
Tarpaulin/plastic	51.85	Type of mechanical huller	
Pre-milling storage		Engelberg (steel rollers)	94.44
Yes	63.88	Abrasive rotating disk)	3.71
No	36.12	Rubber roller type	1.85

4.11. Farmers' knowledge and perceptions of harvest and postharvest losses

The result on farmers' perception on the knowledge and perceptions of rice harvest and postharvest losses are presented in Table 6. Farmers strongly disagreed that postharvest losses do not occur in rice production as indicated by the mean of 1.3. The statement that the level of rice postharvest losses is normal was also strongly disagreed. However, farmers strongly agreed that postharvest losses in rice

Table 6. Knowledge and perceptions of harvest loss and postharvest loss (PHL)

Perception statement*	Mean (SD)
Harvest and PHL does not usually occur in rice	1.3 (0.8)
The level of rice harvest and PHL is normal	1.2 (0.5)
The level of rice harvest and PHL is too much	4.3 (0.9)
The level of rice losses is more prominent at the harvesting stage	4.2 (0.8)
The level of rice losses is more prominent during paddy transportation	3.3 (1.2)
The level of rice losses is more prominent at the threshing stage	4.0 (1.2)
The level of rice losses is more prominent at the drying stage	3.8 (1.0)
The level of rice losses is more prominent at the parboiling stage	3.0 (0.5)
The level of rice losses is more prominent at the milling stage	3.6 (0.8)
The level of rice losses is more prominent at the storage stage	3.5 (0.2)
Harvesting with sickle/knife increases the losses	3.8 (1.1)
Harvesting with a combine or reaper increases the losses	3.3 (1.0)
Threshing with traditional method increases the losses	4.0 (1.0)
Threshing with a mechanical thresher increases the losses	3.3 (0.9)
Drying paddy on tarpaulin or plastic sheet increases losses	3.6 (1.1)
Drying paddy on cemented floor increases losses	3.5 (1.2)
Drying paddy on a raised platform increases losses	3.1 (0.8)
Traditional parboiling method increases losses	3.0 (0.5)
Improved parboiling method increases losses	3.0 (0.5)
Milling with traditional methods increases losses	3.5 (0.9)
Milling with Engelberg huller/machine increases losses	3.7 (0.9)
Rice variety influences the yield at harvest and grain quality	4.4 (0.7)
Good crop management increases total yield and grain quality	4.6 (0.5)
Timely harvesting increases total yield and grain quality	4.7 (0.4)
Good processing and handling methods increase rice yield and quality	4.6 (0.6)

*Strongly disagree (1), disagree (2), indifferent (3), agree (4), strongly agree (5)

were too much as indicated by the mean of 4.3. Results again indicated that losses were most predominant at the harvesting and threshing stages with means of 4.2 and 4.0 respectively. As expected, the results indicated that threshing the rice traditional method increases postharvest losses.

Furthermore, there was strong agreement with the statement that total rice yield and grain quality are influenced by factors such as type of rice variety planted, good crop management practices, timely harvesting of the paddy and good processing and handling methods as designated by the means 4.4, 4.6, 4.7, and 4.6, respectively.

4.12. Cost of production, grain yield and the role of post-production activities

The contributions of the various cost items in the total rice production cost per acre and grain yield are presented in Tables 7 and 8.

The contribution of the cost of harvest and postharvest activities to the total cost of production was considerable (21%) and bigger than all the other specific production activities. This was followed by cost of fertiliser and land preparation. The relatively higher fertiliser requirement (15% of total production cost) suggests that the fields in sampled locations were generally depleted probably due to prolong land use resulting from inaccessibility to farming lands. Government and private sector support may be needed to appropriately develop new paddy fields to assist these farmers in their quest to improve productivity and increase rice production. Furthermore, total postproduction grain loss constituted nearly 20% of grain yield per acre as shown in Table 8. The substantial contributions of

Table 7. Cost of rice production per acre at study locations

Cost item per acre	Mean*	Percent of total production cost
Seed	35.35	9.4
Fertiliser	57.88	15.4
Weedicides	27.67	7.4
Fungicides	8.47	2.3
Land clearing	30.07	8.0
Land preparation	40.94	10.9
Planting	27.61	7.4
Manual weeding	31.45	8.4
Harvesting	42.60	11.4
Threshing	8.22	2.2
Parboiling	0.11	0.0
Drying	21.19	5.7
Milling	6.43	1.7
Transportation	36.02	9.6
Harvest and postharvest activities	78.54	21.0
Total cost of production	374.01	100.0

*Cost in US dollars at an exchange rate of US\$ 1 = GH¢ 4 as in January 2017

Table 8. Proportion of perceived harvest and postharvest losses and grain yield

Item	Mean	SD
Grain loss per acre (%)	19.58	8.73
Grain yield per acre (kg)	167.68	54.19

the cost of harvest and postharvest activities in the total cost of rice production imply that efforts at reducing harvest and postharvest losses will ultimately reduce the production cost and hence increase income from rice farming among smallholder rice framers in Ghana.

5. Conclusions, policy implications and recommendations

From the study, the following conclusions, policy implications and recommendations have been established:

- An overwhelming majority of sample rice farmers (98%) were fully aware of harvest and postharvest losses. However, out of these, 96% of them truly experienced harvest losses on their rice farms whereas 98% have experienced postharvest losses. Additionally, 89.81% and 93.51% of farmer's perceived losses of between 0% and 19% during harvest and postharvest stages, respectively. The above result indicates that harvest and postharvest loss is a serious problem in the study area and the fact that farmers are aware of this issue suggests that well-targeted efforts to reduce harvest and postharvest losses may interest farmers and lead to their easy adoption of appropriate technologies.
- Farmers perceived mechanical factors, environmental factors and socio-economic factors at 43.59% and 43.50%, 23.08% and 9.25% and 22.22% and 37.07% as the most common causes of harvest and postharvest losses respectively in rice production and hence needs to be taken into consideration in the design of appropriate harvest and postharvest equipment. Traditional rice harvest and postharvest methods were also found to increase losses. There is the need to consider all these factors in an attempt to improve the quality of the rice grain.
- Farmers perceived postharvest losses not to occur during production, but only after harvest. Again, the results indicate that it was at the harvesting and threshing stages that losses were predominant. Finally, the total yield and grain quality were influenced by factors such as type of rice variety planted, good crop management practices, timely harvesting of the paddy and good processing and handling methods.
- From the economics perspective, the result shows that harvest and postharvest activities constituted 21% of total production cost, while accounting for nearly 20% of total grain loss. The use of improved technologies and practices (e.g. appropriate mechanisation, rice varieties with lower grain shatterability, proper land management, etc.) for reducing harvest and postharvest losses in rice production is very essential for decreasing the rice production costs for increased incomes among smallholders. This will not only increase rice outputs and productivity but also enhance the quality of grains produced for increased acceptability at the local markets.
- Furthermore, the results show that farmers have taken keen steps in attempting to reduce rice postharvest losses by using harvest machinery and some forms of postharvest equipment. This suggests that the design and fabrication of appropriate harvest and postharvest equipment is already a demand-driven course as it is an essential need among the rice farmers in helping reduce harvest and postharvest losses and ensure good grain quality for increased incomes and food security among rice farmers in Ghana.
- Rice breeders must consider the attributes of Jasmine and AGRA which is mostly cultivated by farmers and develop new improved rice varieties with low shatterability. Also, Agricultural Extension services should ensure that other cultivated rice varieties such as Amankwatia and Togo marshall which are perceived to have significantly lower grain loss due to their characteristically low shatterability becomes easily accessible to farmers.
- This study also identified the critical role being played by rice private out-grower scheme companies in improving total grain yield and enhanced grain quality through the provision of mechanisation support services for rice harvesting to smallholder farmers. It is recommended that the government creates the enabling environment for more of such companies to thrive in an effort to help increase total rice production while reducing the nation's heavy dependence on rice imports.

- The substantially high level of fertiliser usage (15% of total production cost) from the study results indicates the need for proper land management systems in rice-growing areas through both government and private sector support. It is, however, recommended that detailed field studies be conducted in these rice-growing areas to identify the extent and state of nutrient depletion and suggest sustainable solutions to arrest this challenge.

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Competing interests

The authors declare no competing interests.

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