

**QUANTITATIVE LOSS ESTIMATION OF RICE (*Oryza sativa* L.) DURING HARVESTING,
IN-FIELD STACKING, THRESHING AND CLEANING IN THE AKATSI NORTH
DISTRICT OF VOLTA REGION OF GHANA**

BY




**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL
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DECLARATION

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ABSTRACT

The knowledge and perception of farmers in the Akatsi North District of Volta region on harvest and postharvest losses in rice (*Oryza sativa* L.) during harvesting, in-field stacking, threshing and cleaning were assessed using semi-structured questionnaires. Data were collected on 40 farmers who were selected through a multi-stage, purposive, and simple random sampling methods from September 4 to November 23, 2018. Majority (75%) of farmers interviewed had no formal education on postharvest loss (PHL) assessment of paddy rice. Losses were therefore estimated by speculation, using number of bags as a measure. At least 60% of farmers agreed that the losses at the various points of handling were significant enough to reduce their total output. From the survey, the perceived average yield of farmers was 2.46 Mt/ha. The total perceived loss of farmer was 21.56%. In order to confirm or deny the farmers' perceived losses of paddy, a verification field experiment was carried out on 8 farmer fields in three communities, including Ave-Afiadenyigba, Ave-Havi and Ave-Dakpa, to estimate the actual paddy yields and quantitative losses during harvesting, in-field stacking, threshing and cleaning of Jasmine 85 rice variety at two different harvesting times. These were recommended harvesting time at 35 days to harvest after heading (35 DHAH) and farmers' actual days of harvesting. The field experiment recorded an average yield of 3.77 Mt/ha for the Recommended practice and 3.58 Mt/ha Farmers' actual practice. The total losses at the two different times (35 DHAH and Farmers' practice) were 6.38%, 7.65% respectively. To determine the possible changes that may occur in the total grain loss (TGL) across the study area, a Monte Carlos simulation of 10000 trials were performed on each loss variable with Latin Hypercube sampling. The changing scenarios in the TGL were described using a triangular probability distribution model. A sensitivity analysis was performed to determine the loss input variables that are likely to contribute most to the total grain loss. The probability distribution of losses across the study area at

95% level of significance suggested that farmers who harvest Jasmine 85 variety 35 days after heading are likely to experience paddy loss within the range of 15.9 – 28.7 g/m² while those harvesting at the farmers' actual time are likely to encounter total losses ranging from 20.3 - 33.4 g/m². In general, harvesting was associated with highest paddy loss of 9.96% for farmers' perceived losses, 2.63 % for 35 DHAH and 3.17% for farmers' actual losses. However, in-field stacking, with losses of 20.4 – 23.7 g/m² and 24.9 – 28.6 g/m² for recommended and farmers' practices respectively, was identified in the sensitivity analysis as the loss input variable that is likely to contribute most to the total grain loss across the study area. Time of harvesting was however, perceived by farmers as a factor of very high influence on field losses. Reduction in food losses might therefore be achieved through harvesting at 35 days after heading alongside proper postharvest handling practices.

DEDICATION

I dedicate this thesis to my wife, Ernestina Dzifa Tamakloe and my children; Josiah Dgidula Tsortsi and Erel Eyram Tsortsi for their prayers, encouragement and support in diverse ways during this study.

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LIST OF ABBREVIATIONS

CARD	Coalition for African Rice Development
CRI	Crops Research Institute
CSIR	Council of Scientific and Industrial Research
DHAH	Day to Harvest after Heading
EUCORD	European Cooperative for Rural Development
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GRiSP	Global Rice Science Partnership
HRR	Head Rice Recovery
HRY	Head Rice Yield
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
ISSER	Institute of Statistical, Social and Economic Research,

MoFA	Ministry of Food and Agriculture
NERIC	New Rice for Africa
PDF	Probability Density Function
PFJ	Planting for Food and Job
PHL	Postharvest Loss
PHLs	Postharvest Losses
SARI	Savannah Agricultural Research Institute
SRID	Statistical Research Institute Department
SSA	Sub-Saharan Africa
TGL	Total Grain Loss
TGLD	Total Grain Loss Day
TLs	Total Losses
U.N.	United Nations
WARDA	West Africa Rice Development Association

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oriza* spp.) is the most widely cultivated cereal in the world after wheat and the most important food crop for approximately half of the world's population (IRRI, 2009a). Rice is an important cash crop in communities in which it is grown (Angelucci *et al.*, 2013). The crop is the main cereal next to maize and sorghum produced in Ghana with increasing consumption due to growth in population, urbanization and change in consumer habits (MoFA, 2009).

Rice is produced in all the ten regions of Ghana, covering all the major ecological-climatic zones, including the Interior Savannah zone, the High Rain Forest zone, the Semi-deciduous Rain Forest zone and the Coastal Savannah zone (Oteng, 1997). There are different rice ecologies made up of Rainfed dry/upland, Rainfed lowlands or hydromorphic, Inland swamps and valley bottoms and irrigated ecology in each agro-ecological zone. The rainfed ecology (drylands and lowlands) occupies about 75 percent of the production area, the irrigated ecology accounts for 10 percent and the inland swamps and valley bottoms also accounting for 15 percent (Oteng, 1997).

Different rice varieties may thrive in any of these ecosystems. Some rice varieties grown in the Rainfed dry/upland ecology are NERICA 1, NERICA 2, OX 3108 (Sikamo; GR 22) and EMO TEAA (IDSA85). Those cultivated in Rainfed lowland or hydromorphic ecology include JASMINE 85 (SAR-RICE 2; Gbewaa; Lapez), NABOGO RICE, GR 21 (TOX 515-19-SLR), Sakai (ITA-324), Bodia (ITA-320), Wakatsuki (Bouake 189), Marshall (Amankwatia), DIGANG (Abirikukuo or Aberikukugo), GR 20 (IR 1750-F5-B5), GRUG7, GR 18 (Afife) and OX 3108 (Sikamo; GR 22). Inland swamps and valley bottoms varieties are FARO 15, GR 17

(IET 2885) and KATANGA RICE while Irrigation ecology is identified as a favourable environment for JASMINE 85 (SAR-RICE 2; Gbewaa; Lapez) (Ragasa *et al.*, 2013).

The annual production of rice (paddy) in Ghana rose from 185,000 metric tonnes in 2007 to 688,000 metric tonnes in 2016 while milled rice rose from 111,000 metric tonnes to 475,000 metric tonnes over the same period (SRID-MoFA, 2016). The top five production regions were Volta, Ashanti, Eastern, Upper East and Northern with Volta region recording the highest average production value of 206,908.45 metric tonnes (SRID-MoFA, 2016).

Production of rice in the Volta region stretches from the Northern part to the southern part with production areas including South Tongu, North Tongu, Central Tongu, Ketu North, Akatsi South, Ho Municipal, Afadzato South, Hohoe Municipal, Jasikan, Biakoye, Kadjebi, Nkwanta South and Akatsi North (<http://www.ricehub.org/GH/volta/>, 24th October, 2018), where this study was conducted. The production environment of the study area is mainly rainfed lowland ecosystem. The common varieties of rice grown in the study area were Jasmine 85, Togo marshal and Agra with Jasmine 85 being the most widely cultivated one. The basic field production practices adopted by farmers were land preparation with minimum tillage, broadcasting method of planting, chemical weed control, fertilizer application, scaring of birds and to a lesser extent, disease control.

In spite of the various rice ecosystems in Ghana, local rice production is far less than consumption. Per capital consumption rose from 39.2 kg to 45kg between 1985 and 2010 with no equivalent increase in production, leading to high imports to meet demand (Tanko, 2016).

Ghana is about 30% self-sufficient in rice production, producing about 150,000 metric tonnes (MoFA, 2015). As a result rice constituted 58% of all cereal imports in Ghana (CARD, 2010).

Low yields, high harvest and postharvest losses may account for the high importation. Postharvest losses comprise all changes in the palatability, wholesomeness or quality of food that prevents it from being consumed by people (Lindbland, 1978). It also denotes disappearance of the food. These losses occur during drying, winnowing, storing, milling and transportation and could be measured in economic, quantitative, qualitative or nutritional terms.

Harvesting and postharvest losses are usually high among small-scale rural farmers due to delayed harvesting and improper handling of rice at the primary processing stages. The best time to harvest rice is between 28 and 35 days after heading and 32 and 38 days after heading in dry and wet seasons respectively depending on the variety (IRRI,

<http://www.knowledgebank.irri.org/training/fact-sheets/item/when-to-har>. Accessed June 17.

2018). Timely harvesting and proper handling is therefore crucial in rice production to achieve maximum grain yield and minimize loss of grains and quality deterioration (IRRI 2015 and Amposah *et al.*, 2018). Food and Agriculture Organization of United Nations (U.N.) stated about 1.3 billion tonnes of food are globally wasted or lost yearly (Gustavasson *et al.*, 2011).

Postharvest loss assessment of rice in Ghana has faced many challenges including insufficient data on production levels and the magnitude of losses that usually occur with regards to what, where and why the losses occur in the production system (Appiah *et al.*, 2011). However, rice production is given more attention than its loss reduction in Ghana (Kader & Rolle, 2004; Martins, 2013). With estimated postharvest loss of rice for Ghana ranging between 6.3 -19.1% (Kwame *et al.*, 2013), it is necessary that equal attention is given to both production and postharvest loss reduction.

Assessment of farmers' knowledge on yield gaps and postharvest losses is, therefore, vital to identifying and understanding losses at the various points of postharvest chain at the farm level.

Food loss assessment is also important to quantify the main causes of food losses, analyzing the economic impact of the losses and finding solutions to reduce them. In addition, it is a useful tool for making concrete proposals to formulate a food loss reduction programme (FAO, 2016).

A study on loss estimation of rice is therefore useful as it will help farmers to appreciate the levels of losses that occur at different times of harvesting rice and during postharvest handling operations and how to minimize these losses. Understanding farmers' perception about losses at the various stages of production will also help stakeholders in directing efforts and resources toward loss reduction so as to increase production.

This study aimed at estimating field quantitative loss during handling of paddy rice in the Akatsi North District of Volta region. The specific objectives were as follows:

- i. to assess the knowledge and perception of farmers on losses in rice during harvesting, in-field stacking, threshing and cleaning.
- ii. to estimate losses in rice harvested at recommended 35 days after heading and at the Farmer's actual harvesting time (Farmers' practice).
- iii. to predict the likely contributions of harvesting, threshing, infield stacking, cleaning and day to harvest to total grain loss across the farms of the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The origin of rice plant

Rice (*Oryza sativa* L.) is an annual plant belonging to the family Graminae or Poaceae (Agropedia, 2009) and closely related to bamboos but distantly related to the major cereals' maize, wheat, and sorghum (Vaughan,1994). From germination, the plant may take 3 to 6 months to mature based on the variety and the ecological zone (Ranawake *et al.*,2013). The rice plant has prominent vegetative part made of the roots, culms and leaves and the floral part solely made up of the spikelet that support its life cycle. It undergoes a series of developmental processes which start from the emergence of coleoptile to the formation of hard dough on the panicle. Generally, the developmental cycle is categorized as vegetative and reproductive periods. The vegetative phase includes emergence, seedling development, tillering, internodes elongation, culm development. The reproductive phase entails prebooting, booting, heading, grain filling and the maturity stage (Dunand and Saichuk, 2009). After a complete vegetative stage, the plant bears a terminal shoot called the inflorescence (floral part), also known as panicle.

The genus *Oryza* consists of 24 species, with two domesticated species. These are the Asian rice, *Oryza sativa*, which originated in southern and eastern Asia and most widely cultivated rice species in the world and the African rice, *Oryza glaberrima*, which originated in western Africa. There are two subspecies of Asian rice; *japonica* and *indica*, although five distinct groups are suggested to be recognized within *O. sativa* by more recent genetics (Garris *et al.*, 2005).

2.2 Overview of Rice Research in Ghana

Development of new varieties of crops, among others, is one important way to increase agriculture productivity. Use of improved crop varieties results either in increased yields or reduced use of inputs to maintain initial output level. Accordingly, development and introduction of new and improved varieties has become the focus for crop breeders, researchers, and policy-maker to address the challenge of low productivity. Extensive cultivation of rice in Ghana has led to the development of several varietal types. Rice research program in Ghana is mainly conducted by both Crops Research Institute (CRI) and the Savannah Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR) (IFPRI, 2013). Soil and Irrigation Research Centre, (SIREC) of University of Ghana at Kpong is another research centre making great contributions to development of rice research in Ghana. In 2014, Bruce *et al.* explored the effect of improved rice seed adoption on output compared to the adoption of traditional varieties in Ghana. The study demonstrated that the use of improved seeds significantly increased output.

2.3 Introduction of Jasmine 85 variety in Ghana

Several studies have indicated that consumers in Ghana prefer rice with aromatic trait such as Jasmine 85 over those with non-aromatic traits (Abansi *et al.*, 1992; Damardjati and Oka, 1992; Untong *et al.*, 2010). Jasmine 85 is an aromatic rice variety developed in Thailand in 1966 by Doctor Ben Jackson, a rice breeder in the International Rice Research Institute. In 1989, the USDA in the collaboration with IRRI, University of Arkansas, Louisiana State University, and Texas A&M University, released Jasmine 85 to American farmers. The registration number of this variety is CV-107, PI 595927 and it is characterized as Irrigated and rain-fed Lowland rice (Oluyemi, 2014). This variety was introduced in the system of Ghana's Savana Agricultural

Research Institute (CSIR-SARI) in 1998. The variety has been chosen because of its characteristic aroma, grain size and grain length (Diako *et al.*, 2011). The variety also has a potential high yield of about 4.5 – 8 tons per hectare and matures within 110 – 120 days. This has made it the most preferred rice variety for rice farmers (Ragasa *et al.*, 2013). The Aroma in Jasmine 85 is attributed to the presence of 2-acetylcysteine (2AP) (Napasintuwong, 2012; Oluyemi, 2014).

Different sources of Jasmine 85 are produced in Ghana. A cluster analysis run on the morphological and physico-chemical data gave four clusters; (GBEWAA and TONO), (SARI), (PV), (KIP, CRI, ARI, DARTEY). The molecular data on the other hand gave three clusters: (TONO, DARTEY,PV), (SARI,ARI, CRI), (KIP, GDEWAA) (Oluyemi, 2014).

2.4 Economic Importance of Rice

Rice, wheat and maize are cereals widely used as food in the world (Kumar and Kalita, 2017). Rice supplies about 20% of the calories needed to over three billion people depending on it as staple food worldwide (Saed *et al.*, 2011). The crop has also become one of the preferred foods that provide the Africa's growing population with bulk of dietary energy. According to Kassali *et al.* (2010), as cited by Aremu and Akinwamide (2018), rice accounts for 715/cal/caput/day, 27 percent of nutritional protein and 3 percent of nutritional fat. In addition, rice also provides raw material for industrial use. In West Africa, the crop is an important food for households and for the domestic economy (Togola *et al.*, 2010).

Growth in population and change in food habit of people have led to increased consumption of rice in Ghana (MoFA, 2009). As a result, rice constitutes 58% of cereal imports in Ghana (CARD, 2010). The role of rice in the development of the economy of Ghana cannot be

underestimated. Institute of Statistical, Social and Economic Research (ISSER, 2000) reported that rice contributed nearly 15% of the gross domestic product (GDP) of the country.

2.5 Rice Production and Consumption

2.5.1 Production and Consumption in the World

Almost half of the world's population depends on rice as staple food crop (IRRI, 2009a). The current world population of 7.7 billion is projected to grow to around 9.7 billion in 2050 (United Nations, 2019). According to FAO (2019), the world's rice consumption is projected to expand to 503.9 million tonnes (milled basis) in 2018. Meanwhile the global paddy production forecast by FAO in 2017 (756.7 million tonnes) has been raised by 2.9 million tonnes to 759.6 million tonnes (503.9 million tonnes, milled basis). The ever-increasing world's population coupled with the increasing food demand suggests that practical approaches need to be identified to meet consumption requirement. To meet the global demand for rice, production is forecast to grow by 1.4 percent. This will result in annual expansion of output by 10.3 million tonnes to a new production level of 769.9 million tonnes (510.6 million tonnes, milled basis) (FAO, 2018).

2.5.2 Production and Consumption in Africa

In developing countries, cereals supply about 60 % of total calories consumed of which rice is the most important source (Awika *et al.*, 2011). Rice is an important food crop in Africa where activities related to its production, handling and consumption are extensively considered a solution for the development of the economy, food security, and reduction of poverty (Tollens, 2006; Velde *et al.*, 2014; Demont *et al.*, 2015). It is the food product mostly demanded and traded in very large quantities on the continent (Tollens, 2006; Laroche *et al.*, 2013). While the consumption of rice in Sub-Saharan Africa (SSA) has significantly shot up since 1995 and

growing faster than in any other part of the world, per capita consumption in parts of Asia is declining (Mohanty, 2013). Over the past 50 years, rice imports in Africa grew 2 % yearly and reached 43 % in 2009. About one-third (11.8 million tonnes) of rice was reported to have been imported by African countries in 2011 as compared to 0.5 million tonnes in 1961 (Nasrin *et al.*, 2015). The estimated import bill for Africa was US \$4.3 billion annually (Nakano *et al.*, 2013). Faced with rapid population growth and growing per capita rice consumption, policy makers of Africa countries have the option of either importing more rice or expanding production per unit area or combination of the options to meet the growing demand. (Van Oort *et al.*, 2015).

There had been efforts to increase production through area expansion and increase in productivity since 2000 in Sub-Saharan Africa (SSA). However, achieving self-sufficiency has not been realized so far (van Oort *et al.*, 2015). Demand has persistently exceeded local supply for the past 50 years (WARDA, 2007; FAO, 2012; IRRI, 2012), suggesting self-insufficiency in rice production of most SSA countries (van Oort *et al.*, 2015). Meanwhile, the population and per-capita rice consumption are projected to increase significantly (UN, 2014). This implies that either more land area is cultivated or more imports of rice or combination of the two will be needed, if growth in yields cannot cater for the increasing consumption (Van Oort *et al.*, 2015).

2.5.3 Production and Consumption in Ghana

The agricultural sector is vital for human survival. The sector is noted for supplying food for domestic use, industrial raw materials and generation of income for communities and households that engage in production activities all over the world. Crop production has been a livelihood option for many, especially the rural communities in Ghana. Among the major crops cultivated in Ghana, rice has been noted as the second largest cereal consumed after corn (Ashitey and Archibald, 2018) and one of the most cultivated cereal in the country (Taiwo and Bart-Plange,

2016). The domestic production, 185,000 metric tonnes in 2007, increased to 688,000 metric tonnes in 2016 (Table 2.1). Although there has been a rise in domestic production, consumption still far exceeded local production. The commodity was reported to constitute 58% of all the country's cereal imports (CARD, 2010). The share of domestic rice production decreased from 55% in 2014 to 44% in 2016 and later increased slightly to 47% in 2017 (Table 2.2). The increase in production within the period was due to improved yield per unit area. Recently, the government has promoted the local rice production through the Planting for Food and Job (PFJ). Input supply (seed rice and fertilizers) and extension activities have been increased (MoFA, 2017). Increase importation of rice in Ghana is attributed to taste and preferences of consumers for foreign rice over the years. With high annual average import bill of US\$376 million, extra effort is required to cut down the level of rice importation (MoFA, 2017).

Table 2.1 Annual productions of major cereal crops, ('000mt) in Ghana

CROP	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Maize	1,220	1,470	1,620	1,872	1,683	1,950	1,764	1,769	1,692	1,722
Millet	113	194	246	219	183	180	155	155	157	159
Rice(paddy)	185	302	391	492	463	481	570	604	641	688
Rice(milled)*	111	181	235	295	278	332	393	417	443	475
Sorghum	155	331	351	324	287	280	257	259	263	230
Total	1673	2297	2608	2907	2616	2891	2746	2785	2754	2799

Source: SRID-MoFA (2011)

Table 2.2 Rice Production and Import in Ghana

Item		2012	2013	2014	2015	2016	2017
Transit Import	(@15%)	76,288	96,650	62,041	93,122	104,659	98,434.81
Total Imports		508,587	644,334	413,609	620,811	697,728	656,232.06
Imports Available (Total less Transit)		432,299	547,684	351,568	527,689	593,069	557,797.25
Domestic Rice Extraction Rate)	Milled (@69%)	331,898	392,972	422,829	443,000	474,498	497,018
Total Rice Available (MT)		940,656	774,397	970,689	764,197	1,067,567	1,054,815
Share to Total Supply by Source							
		2012	2013	2014	2015	2016*	2017
Domestic Rice		43%	42%	55%	46%	44%	47%
Imports		57%	58%	45%	54%	56%	53%

Source: Agricultural Sector Progress Report (MoFA, 2017)

2.5.4 Production in Volta Region

Volta region is noted for rice production on a large scale in Ghana. The region recorded the highest average production value of 206,908.45 metric tonnes among the top five rice producing regions in the country (SRID -MoFA, 2016). Rice in the region is cultivated under rainfed and irrigated ecologies. Afife Irrigation Project in the Ketu-North District and the Aveyime Irrigation Project in North Tongu are located in the region and are well-known for large scale production (Taiwo and Bart-Plange, 2016).

2.6 Harvest and Postharvest Handling Operations

2.6.1 Harvesting

Timely harvesting of paddy is crucial to prevent crop loss and ensure quality grain for high market value. It is a vital operation that can increase the quantity of paddy rice (Alizadeh and Allameh, 2013). Ali *et al.* (1990) and Hossain *et al.* (2009) investigated the effect of harvesting time and indicated that it had a great impact on paddy moisture content and head rice yield (HRY). Paddy with lower moisture content than the optimum level will result in high percentage broken grains. The optimum moisture content to harvest paddy ranges between 15% and 22% (Nalley *et al.*, 2016). The best time to harvest rice is determined based on both, the head rice yield (HRY) and the physicochemical and nutritional characteristics such as moisture content, protein content, milling suitability, and taste (Asano *et al.*, 2000) as cited by Hoon Kim *et al.*, (2016). Harvesting at 28 to 35 days after heading in the dry season and 32 to 38 days after heading in the wet season are the recommended optimum times of harvest for optimum grain yield. Harvesting too early will cause low yield as a result of a higher percentage of unfilled or immature grains (IRRI, 2013). Delayed harvesting also increases grain and panicle shattering and lodging of rice stalks (Mohammad *et al.*, 2013).

2.6.2 Threshing

Threshing involves detachment of the paddy rice from the panicle either by rubbing, impact or stripping (Muhammad and Shahid, 2010). Threshing methods vary with individual farmer based on the scale of production. Threshing is generally done manually or mechanically. Manual threshing is done either by beating bunches of panicles against hard elements such as wooden box (bambam), logs and tables or by treading the panicle underfoot by humans or animals (Food

Agency Organization 1995) cited by Olugboji (2004). Others are Hand-held threshers and pedal operated threshers.

Currently motorized threshing machines are gradually being replaced by combine-harvesters in Ghana (QUAYE, 2016). A study conducted by Amponsah *et al.* (2018) across three agro-ecological zones of Ghana (coastal savannah, forest and guinea savannah) showed that over 50% of the farmers used combine harvester for threshing, 36% used the threshing by impact “bambam” method, 11% bag beating and 2% used mechanical threshers.

Threshing may have effect on rice quantity, quality and must therefore be considered an important operation in the production process (Alizadeh and Bagheri, 2009; Alizadeh and Allameh, 2013). The method of threshing may vary with location. Manual threshing, though associated with lower cost, may lead to as high as 20-30% quantitative and qualitative losses (Rickman *et al.*, 2013), depending on the type of method used (Guisse, 2010). In Malaysia, a threshing loss was estimated between 5% - 13% while the Philippines experienced 2% - 6% loss (FAO, 2007).

2.6.3 Cleaning

Cleaning is important in improving quality and safe storage. Grain loss and lower head rice yield (HRY) occur when there is improper cleaning. Bulkiness in subsequent postharvest handling operations is reduced when paddy cleaning is well done. Cleaning may be done manually with wind energy or mechanically (Madhu *et al.*, 2013).

2.7 Farmers’ Perception about Yield Losses of Rice at Farm Level

Understanding how farmers perceive losses that occur during harvesting and handling is essential in identifying the levels of yield gaps and postharvest loss awareness (Abass *et al.*,

2014). Postharvest losses (PHLs) are combination of factors which influence farmers' interaction with technologies or practices and the perspective in which they function (World Bank, 2011; Kagbu *et al.*, 2016) and perception is pivotal in this phenomenon. Postharvest loss perceptions are defined as inherent factors such as attitudes, values and beliefs about PHLs that influence farmers' willingness to reduce the losses (Martin *et al.*, 2014). Sebagala *et al.* (2017) argued that PHLs on the field are as a result of farmers practices or behaviours based on their norms and belief, thus they have the ability to reduce them. Efforts to reduce PHLs can only happen if the losses are recognized by farmers as a problem affecting them and their involvement is needed to reduce the losses. Farmers who understand that their income and availability of food are affected greatly by PHLs will show the desire to accept new knowledge and technologies to cut down the losses (Rogers, 1995; Seline *et al.*, 2015). This implies that those farmers who do not consider it as a problem that affect their livelihood significantly may continue with their traditional practices.

2.7.1 Postharvest loss assessment

The international standard of measuring grain loss is by weight loss because it helps to quantify the national effect of losses and also to compare losses across the various regions and years (De Lima, 1979a). Grain weight loss may be estimated by either collecting and weighing shattered, split and scattered grains during postharvest operations such as harvesting, threshing and transport or by measuring the weight of the remaining grains after a postharvest activity such as storage where portions of the grains may be consumed by pests (Hodges *et al.*, 2012). A lot of commitment has been made over the years to increase agricultural production, yet inadequate attention has been paid to reduction in postharvest losses, especially in cereals (Hodges *et al.*, 2011; Affognon *et al.*, 2015). Food and Agriculture Organization (FAO, 2011) recorded a loss of

13.5% of the total cereal production, including rice, during postharvest handling and distribution in Sub-Saharan Africa (SSA). Yet rice is a major staple food, feeding about half of the world's population (EUCORD, 2012). In view of that, food security can only be enhanced through investment in PHL reduction (Affognon *et al.*, 2015).

Postharvest losses affect livelihood of people engaging in agriculture production and must therefore be measured in economic, quantitative, qualitative or nutritional terms (FAO, 2007). Spoilage, caused by inadequate modern transport and storage facilities, finance, managerial skills and limited technology for postharvest handling, under difficult climatic conditions, are contributing factors of high losses at the postharvest and processing stage in developing countries (Gustavsson *et al.*, 2011). Estimates showed that postharvest losses of food grains in developing world for mishandling and spoilage claimed between 25% and 40% of food crops produced (Saunders *et al.*, 1980; Sadiya and Hassan, 2018).

2.7.2 Harvesting losses

Timely harvesting and proper handling of rice are crucial to get the best yield out of the rice production and also reduce grain losses and deterioration in quality (IRRI, 2015). Physical grain losses occur during cutting of rice stalks, piling of the cut stalks in smaller heaps and when transporting the stalks to main threshing floor (Candia *et al.*, 2012). Improper methods of harvesting and threshing might lead to losses of up to 5% of grains (IDRC, 1976). In some cases, these losses may increase up to 10% (Hodges and Maritime, 2012). FAO (1989) attributed about 25% of postharvest losses of rice to mishandling rough rice and the untimely manner of harvesting. Harvesting and postharvest losses may also differ for the same variety of rice and environment. For instance, Appiah *et al.* (2011) estimated that harvesting losses in rice were 1.39% and 2.93% for panicle harvesting and sickle-harvesting methods respectively. Threshing

losses were 6.14% for ‘bambam’ method, 2.45% in the bag beating method while harvesting losses ranged between 3.03% and 12.05% at farmer’s fields

2.7.3 Threshing loss

Grain loss due to beating with sticks occurs because of incomplete removal of grains from the rice straw pinnacles and scattering of grains due to the impact force (Candia *et al.*, 2012) and also, when the bundles are lifted just before threshing. It may also occur when grains stick in the mud floor. Manual threshing method can lead to quantitative and qualitative losses as high as 20-30% (Rickman *et al.*, 2013), depending on the type of method used (Guisse, 2010). However, it is popularly used due to its associated low cost.

The threshing losses recorded for NERICA variety in bag beating method was 0.53 - 4.07% (Appiah *et al.*, 2010). Loss due to scattered paddy in using the Fomena hand operated rice thresher in Ashanti region of Ghana was 7.7% (Duah, 2017). Also, a “Bambam” box method, in a study conducted by Ramatoulaye (2010), recorded a loss of 6.14%. In Malaysia, a threshing loss was estimated between 5% - 13% while the Philippines suffered 2% - 6% loss (FAO, 2007).

2.7.4 Causes of Postharvest Losses

Scale of loss of grain at various points of the supply chains may differ with respect to the agricultural practices, climatic conditions of a region and handling of the produce until the final stage of use. These losses may generally happen as a result of socio-economic, biological, chemical, mechanical and environmental factors (Harris and Lindblad, 1978). A number of these factors may combine to influence losses at any point in time (Lantin, 1999). Environmental causes responsible for harvest and postharvest losses of rice include insects, vermin, moulds, temperature, weather conditions and humidity (Global Strategy, 2015). High temperature is

noted for reducing rice yield (Ziska and Bunce, 1998). The effect was thought to be due to higher loss of carbon through increased respiration. High temperature has been reported to increase yield (Welch *et al.*, 2010), most probably through improving accumulation of assimilates, lower respiration, higher tillering, leaf-area expansion, stem elongation, faster grain filling, and crop phenological development (Peng *et al.*, 2004). Saunders *et al.* (1978) as cited by Sadiya *et al.* (2018) reported that lack of adequate processing equipment causes as much as 40% loss of the total production in rice. Shatterability and yield are some of the factors considered as biological causes of losses in rice.

Food and Agriculture Organization (FAO, 1989) as cited by Taiwo (2012), stated delayed harvesting, heavy use of traditional methods of threshing, heavy rainfall during harvesting and drying seasons as factors that significantly influence losses. Moisture contents, storage structure, biological and micro-biological factors are critical factors influencing losses (Samajpati and Sheikh, 1980). Storing at reduced moisture contents of about 13% prolong the storage life and maintains viability of seeds while safe storage life of rice is reduced when moisture content is 16% or higher (Michael, 1978). Christensen (1974) added that rice is safely stored when moisture content is in equilibrium with 70% or less relative humidity. It was reported by Alam *et al.* (2007) that about 2.33% loss of rice grains occurred due to storage structure. Hall (1970) identified beetles and moths as main storage pests that cause losses and deterioration of stored rice in the tropical countries.

2.7.5 Importance of Postharvest Loss (PHL) Reduction

Market value of crops is reduced through weight and quality loss which can render the crop less suitable for human use (Fox, 2013). Thus, postharvest loss reduction is critical in enhancing food security. For efficient reduction in losses it is imperative to know the pattern and levels of these

losses as they occur in the production system across the world (Kumar and Kalita, 2017; Appiah *et al.*, 2011). About one-third of the food produced in the world (about 1.3 billion tonnes), worth \$1 trillion, is lost during postharvest operations yearly (Gustavsson *et al.*, 2011). Hence, a cut down in postharvest loss (PHL) of grains will allow farmers to retain more of their produce to increase supply of grains (Goldsmith *et al.*, 2015). Reduction in grain loss will also make more food available for human utilization, improve global food security and also improve real income for consumers (Mundial, 2008; Trostle, 2010; World Bank, 2011). Further, minimizing postharvest losses will help cut down rice import bills. This suggests that PHL reduction will be a very important economic driver of countries whose growth and development revolve around agricultural industry.

2.7.6 Factors Influencing Paddy Loss at the Farm Level

2.7.6.1 Weather Condition

Increasing temperatures and uncertainty of rainfall caused by changes in climate is a threat to agriculture production worldwide (Fisher *et al.*, 2015). The projection of Intergovernmental Panel on Climate Change (IPCC) for 2050 indicated that irregular rainfall, rise in temperature, flooding and droughts, might reduce rice and wheat production by 8 and 23% (Cancelliere *et al.*, 2007) as cited by Rahman *et al.*(2017). Therefore, a better knowledge about the effects of climatic factors on quality of rice will provide information for breeding and developing new varieties of rice that can adapt to change in climate (Xiangqian and Melissa, 2013).

One of the challenges of increasing production of rice is global warming which leads to decline in yield of rice (Peng, 2004; Welch, 2010). Higher minimum temperature was noted to reduce the output of rice (Ziska and Bunce, 1998). In contrast, higher maximum temperature showed increase in yield (Welch *et al.*, 2010). Temperature rise affects both yield and quality of grains.

Chalkiness was found to increase with increasing temperatures both in the day and night. This reduces the quantity of polished and marketable rice through increased grain breakages during dehulling and polishing, leading to a decrease in the amount of acceptable or marketable polished rice (Fitzgerald and Resurreccion, 2009)

2.7.6.2 Harvesting Time

Head rice yield (HRY) is significantly affected by harvesting such that harvesting paddy rice at optimum moisture content is required to achieve the best HRY. Paddy harvested at moisture content lower than the acceptable level, will have the percentage broken rice increase significantly (Hossain *et al.*, 2009). Determination of optimum harvest time is crucial for maximizing head rice yield. When harvesting is delayed, grains shatter and fissures develop in rice grains, leading to breakage during processing while harvesting earlier than required will also result in losses due to higher percentage of under-developed green kernels and low head rice recovery (Singh *et al.*, 2000). Chaudhary and Iqbal (1986), cited by Singh *et al.* (2000), stated that maximum head rice recovery (HRR) was obtained when the rice crop was harvested at 35 days after 50% flowering at moisture content ranging from 20-22%, but decreased when harvesting delayed beyond this period. Harvesting at 33-39 days after 50 % flowering gave significantly higher head rice recovery than 27-30 days or 42 days after flowering (Salim and Sagar, 2003).

2.8 Challenges of Farmers

2.8.1 Farmer Education

Agriculture is main source of livelihood for many people in developing countries. Agriculture was the largest employer, accounting for over 50 percent (50.6%) of total workforce (Ghana Statistical Service, 2010). With greater population of the country being rural dwellers, adoption

of agricultural technologies and enhancing agricultural production may possibly be an important alternative for reducing poverty among the rural dwellers. Extension service and education have been considered critical tool for rural development through boosting agricultural productivity, ensuring food security and reducing poverty. This is because Extension Education has the means of transferring information and agricultural knowledge through technology and also, helping farmers to develop the interest in solving problems (Christoplos and Kidd, 2000). Through Extension Education, information on new technologies for improving production, incomes and standards of living are provided to farmers (Bonye *et al.*, 2012). Information and education give a positive outcome to agriculture (Oladele, 2006; Bachhy, 2012). The ease of accessing information has the ability to positively affect the behaviour of farmers in handling agricultural produce (Asiabaka and Kenyon, 2002). Hence investment in agricultural education is vital for increasing output.

Production of food in Africa, including Ghana, is dominantly carried out by small farm holders whose areas of cultivation are usually less than 2 ha (Donkor *et al.*, 2016). Statistics show that whereas demand is estimated to be 960,000 metric tonnes, domestic production was 300,000 metric tonnes, representing only 31.25% of the local demand (SRID, 2013). Meanwhile, agricultural yields have been targeted to grow averagely at the rate of 4% per annum for the period 1996-2020 (Vision 2020 document, 1995). The fact that supply fell far below demand suggested that more investment in agricultural education, to provide information on good agricultural practices (GAP) to the rural farm holders, who contribute most to the food basket of developing countries, is urgent.

A study conducted by Duraisamy (1992) revealed that a one-year increase in farmer's education and extension contacts of farm household head raised production by 1% and the total sales value

for all crops by 4 %. The effect of extension education on output was found to be about 6 % and on the gross value about 10 %. By these observations, investment in formal schooling for people in rural communities and extension services are needed to accelerate agricultural growth.

2.8.2 Destruction Caused by Birds

Birds are identified by the Global Rice Science Partnership (GRiSP) as key biotic factors, next to weeds, limiting production of rice in African (IRRI *et al.*, 2010). About 15% of rice produced globally is lost to animal pests, including birds (Oerke, 2005). Birds caused 19% loss of rice in the humid zone (de Mey and Demont, 2013). In West Africa, birds were reported to cause a damage of 13.7% to rice (Manikowski, 1984). The losses caused to cereals, including rice, by birds in Nigeria was valued \$2.8 million per year (Pearson, 1967; De Grazio *et al.*, 1971; Ward and Jones, 1977) cited by de Mey and Demont (2013).

2.8.3 Labour

In developing countries socio-economic factors and lack of agricultural technology are the main causes of rice harvest losses. Rice losses at the end of the postharvest supply chain are notably higher for developing countries than in developed countries. This is because manual harvesting, which requires so much labour and a slow process, is mostly performed in developing countries. During climax of the harvesting season, most countries experience shortage of labour, which causes delayed harvesting and subsequent high losses (Kumar and Kalita, 2017). Labour shortage is among the reasons for production of low quality rice in Ghana (Akolgo *et al.*, 2015). How soon harvesting is done after the rice has reached maturity is largely dependent on labour availability. For instance, readily available labour ensures timely harvesting, which is vital for loss reduction. Delayed harvesting due to inadequate labour leads to higher losses caused by shattering, lodging and exposure of grains to pest attack. A study conducted in Punjab, India,

found harvesting losses in wheat increased from 1.5% to 2.5% (67%) due to a delay in harvesting (Grover and Singh, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study was carried out in the Akatsi North District of the Volta Region from August, 2018 to July, 2019. The district is located in the south-eastern part of the Volta Region and has a land area of 314.15 square kilometers. It lies in the Coastal Savannah Equatorial climatic zone characterized by high temperatures (minimum 21^oC and maximum 34.5^oC), high relative humidity of 85% and a moderate-to-low rainfall regime of 1,084 millimetres with distinct wet and dry seasons of about seven months (Ghana Statistical Service, 2014). The vegetation type of the district is Coastal Savannah in the south and Savannah Woodland in the north. The area is relatively low- lying with portions close to rivers and streams becoming seasonally waterlogged and marshy. This makes it suitable for rice farming. The common varieties of rice grown in the study area are Jasmine 85, Togo marshal and Agra with Jasmine 85 being the most widely cultivated variety.

Other agricultural activities undertaken in the area aside crop farming are livestock and poultry farming.

3.2 Outline of Study

The study was carried out in two sections: a field survey and a field experiment. The field survey was carried out to assess the level of awareness and perception of farmers on time of harvesting and post-harvest handling losses. Secondly, technology – verification experiment was carried out to assess the level of losses that do occur during harvesting through shattering, in-field staking, threshing and cleaning in the farmer’s field.

3.3 Assessment of Knowledge and Perception of Farmers on Postharvest Losses

3.3.1 Survey

3.3.2 Sample and Sampling Procedure

A multi – stage sampling approach was adopted in selecting the farmers. Volta region was purposively selected at the first stage because it is a major rice producing region. Akatsi North was selected in the second stage based on the fact that, the area is known for producing rice in the region. The purposive selection of the area was further based on lack of documented data or information on the quantitative loss assessment of rice during production in the district.

Forty farmers, out of about fifty (50) rice farmer population, were selected from Five (5) communities which were chosen purposively with respect to their involvement in rice production. Eight (8) farms, from three conveniently sampled communities, were used for the Field-verification experiment. The communities used in the study included Ave-Dakpa, Havi, Ave-Afiadenyigba, Dzadzefe and Agormor.

3.3.3 Data Collection

Interviews and self-administered pre-tested questionnaires were used to collect data on rice farmers in the selected communities from September 4 to November 23, 2018 (Appendix I) Data were categorized into three sections. Section I was on background information about the respondent. Section II was based on knowledge and perception of farmers about postharvest losses at the farm level and how they estimate them. Section III was based on challenges of farmers.

3.3.4 Analysis of the survey data

Rice farmers' perception and estimated losses were presented as means, standard deviations and percentages using Excel and Genstat 12th edition software.

3. 4 Field Loss Estimation at the Recommended (35 days to harvest after heading – 35 DHAH) and Farmers' Actual Harvesting Days (farmers' practice)

In order to confirm or deny the farmers' perceived field losses of paddy rice in the Akatsi North District, a verification field experiment was conducted on the recommended practice (35 DHAH) and the farmers' actual days of harvesting in eight farmer fields. The three communities of the experimental fields were far apart but the distance between experimental fields in each community was about 500 m.

3.4.1 Demarcation of Experimental Plots

Two pairs of quadrats (plots), of size 3 m x 3 m each, were demarcated in two different locations on each of the eight (8) farms. The quadrat pairs were about 50 m apart. Each pair of quadrats consisted of a plot for recommended practice which was harvested 35 days after heading (Quadrat A) and a plot for the farmer's practice which was harvested on the day each farmer deemed it fit to harvest his or her crop (Quadrat B) as shown in plate 3.1.

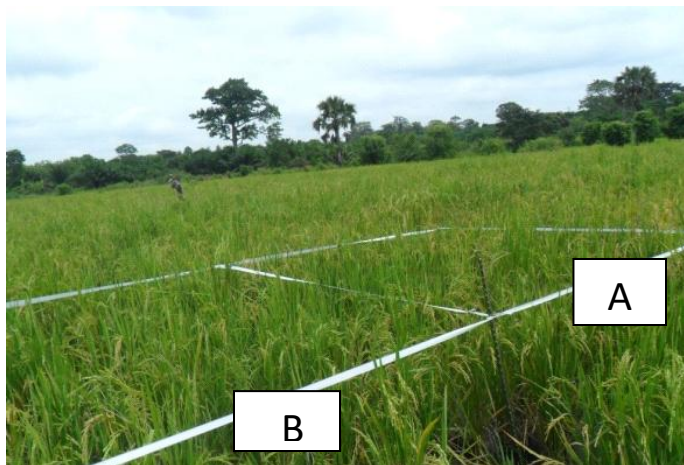


Plate 3.1 A Demarcated Pair of 3m x 3m Quadrat

3.4.2 Agronomic practices

All agronomic practices undertaken in the farmer fields were the same for both recommended practice and farmers' practice except days to harvesting after heading which was different. The agronomic practices undertaken by the farmers included field preparation, planting, weed control, fertilizer application, pest control and harvesting.

Planting was done by broadcasting the seeds in the field at the rate of 125 kg/ha. Planting was done at varied dates between September 14 and September 20 in the eight experimental fields.

Fertilizer was applied in two phases. Phase 1 was done 28 days after planting where N.P.K. 15:15:15 was applied at the rate of 120 kg/ha. Urea was applied at booting at the rate of 60 kg/ha in the second phase.

Weed control was done ones using chemicals. The weedicides used were Nominee and Bensome rice at rate of 617.3 ml/ha and Rice star at the rate of 2.5 L/ha.

The major pests at the study area were birds which were scared continually after the reproduction stage to harvesting time.

Harvesting was carried out in two phases in the experimental fields. The first phase was done at the recommended number of days after heading (35 days) and the second phase at varied number of days of the farmers' choice (farmers' practice). Harvesting was done manually for both practices, using sickle, in all the rice fields.

3.4.3 Harvesting and Yield Determination

Panicles were harvested from quadrat A at 35 DHAH while panicles from quadrat B were harvested on the days farmers actually harvested the crops in their fields (farmers' practice).

The harvesting was done manually with sickle using the expertise of the farmer. The harvested panicles were threshed, cleaned and weighed. This was repeated in all the eight (8) farms.

3.4.4 Harvesting Loss Determination

The shattered grains and panicles that were not harvested during the harvesting operation on the demarcated plot constituted the harvesting loss. The leftover panicles were harvested, threshed, cleaned and weighed separately. The shattered grains in the marked area were immediately collected, cleaned and weighed separately as the shattering loss (Plates 3.2).



Plate 3.2 Collection of shattered grains

3.4.5 Determination of In-Field Stacking Losses

The losses that occur during intermediary piling of harvested panicles before threshing were determined for each quadrat of the eight-farmer fields. The panicles harvested from each plot were placed on a tarpaulin to trap the paddy that would have dropped into the soil if tarpaulin was not used. The dropped paddy on the tarpaulin after bundling the straw for threshing was collected, cleaned and weighed as the in-field stacking loss (Plates 3.3 and 3.4).



Plate 3.3 Harvested panicles



Plate 3.4 Dropped paddy on tarpaulin

3.4.6 Determination of the Threshing Loss

The losses resulting from paddy threshing were determined for each of the 9 m² quadrats on the eight (8) farms. The threshing was done manually using the wooden box method. The threshing loss consisted of the scattered kernels and the residual kernels on the threshed straw. The threshed paddy from the quadrat was first collected, cleaned and weighed. The scattered grain which fell outside the farmer's threshing floor (tarpaulin) during threshing were trapped by making an extension of the threshing floor. The trapped grains were collected, cleaned and weighed. The residual grains on the threshed straw were also carefully sorted, re-threshed cleaned and weighed (Plates 3.5 and 3.6).



Plate 3.5 A farmer threshing paddy



Plate 3.6 Re-threshing of the residual paddy

3.4.7 Determination of Cleaning Loss

Cleaning loss was determined using the grains recovered from the debris of the main cleaning process of the paddy. The paddy was cleaned by winnowing on a large tarpaulin after it was threshed. The unfilled grains, the foreign matter and the filled grains (debris) that were carried away by the force of the wind were trapped and collected. The debris was cleaned the first time to recover the filled grains. Debris collected after the first cleaning process was cleaned again to recover the grains that were not recovered in the first process. The recovered grains in the second cleaning process represented the cleaning loss.

3.4.8 Determination of Moisture Content of Paddy at Harvest

The field moisture content of paddy harvested from the various farmer fields at different times was determined immediately after harvesting using a moisture meter. Three samples, about 10 g each, of paddy were randomly taken from every quadrat at harvest, fed into the moisture meter and the moisture content recorded. The mean of the three (3) readings represented the percentage moisture content of the paddy rice at harvest (Appendix II). The average field moisture content at

harvest was 15.5% for the recommended practice (35 DHAH) and 14.8% for the farmers' practice

3.4.9 Estimation of Field Losses

Loss estimation was done by weight and percentages. The percentage weight loss was computed using the formula (Boxall, 1986).

$$\text{Percentage Loss (\%)} = \frac{\text{Residual Paddy Rice}}{\text{Attained Yield of Harvested Area}} \times 100$$

[Residual paddy was grain mass that constituted loss at each point of assessment in the field].

3.4.10 Analysis of Field Experimental Data

The field data on yields of the two harvesting times were analyzed in a t-test ($p < 0.05$) while losses at the four major points of assessment (harvesting, in-field stacking, threshing and cleaning) for two practices were subjected to analysis of variance (ANOVA) and means with significant difference ($p < 0.05$) separated with least significant difference (LSD) test using the 12th edition of GenStat Statistical Software. Descriptive statistics were used to summarize the data.

3.5 Relative Contributions of the Loss Variables to the Total Grain Loss (TGL)

3.5.1 Description of the model

Simulation modeling in crop loss analysis is useful in at least two important areas: to produce estimates of likely crop losses caused by one or several yield reducers and also, to assess and rank the importance of yield reducers in terms of crop losses (Savary and Willocquet, 2014).

Determination of losses contributed by each input loss variable to the Total Grain Loss (TGL) in this study required that the field loss assessment data were modeled to a Probability Density Function (PDF). This allowed sensitivity analysis to be done to assess the relative contribution of each measured input loss variable to the Total Grain Loss, which usually is an arithmetic sum of the values of the input loss variables (Shattered grains loss, Incomplete cutting loss, In-field stacking loss, Scattered grains loss, Unthreshed grains loss and Cleaning loss). Furthermore, a new index, Total Grain Loss Day (TGLD) (in a fashion of Degree Day), was created to link TGL with the number of Days to Harvest After Heading (DHAH) to serve as a dependent index for sensitivity analysis to be performed with DHAH as an input variable. This TGLD index was conceptually developed to have a biological realism, such that it is directly proportional to both TGL and DHAH in the following equation:

$$\text{Total Grain Loss Day (TGLD)} = \text{Total Grain Loss (TGL)} \times \text{Days to Harvest after Heading (DHAH)}$$

The conceptual framework of the relationships is shown in a general pathway model below (Figure 2).



Figure 3.1 Conceptual pathway model of the TGLD index

3.5.2 Specification of the Loss Input Variables

Shattered grains: Rice grains that fell off the plant before and during harvesting. These grains usually are not collected by farmers and so constituted a loss. The shattered grains were considered as a component of harvesting loss in the study.

Incomplete cutting loss (Unharvested panicles): Matured panicles that were missed during harvesting and left in the field. These panicles were harvested and considered as part of harvesting loss.

In-field stacking loss (intermediary piling loss): This constituted rice grains that dropped on the soil when the harvested straw was put into smaller heaps during harvesting. These grains usually are not collected by farmers and, therefore, constituted a loss.

Scattered grains: Rice grains that fell outside the threshing floor (tarpaulin) of the farmer due to the applied force during threshing and never accounted for in the total yield by farmers. Scattered grains were considered as threshing loss in the study.

Unthreshed grains: The grains of rice which were not removed from the panicle during the threshing process. The unthreshed grains formed part of the threshing loss.

Cleaning loss: Grains retrieved from debris after the paddy was cleaned. These grains usually are discarded with the debris by farmers.

Total grain loss (TGL): Summation of the different measured losses of all the variables considered.

Day to harvest after heading: The period between the day the panicle of rice is fully visible to the day the panicle is harvested. This computation was done in number of days and started when the plants were about 80% headed during the study.

Total grain loss day index (TGLD): The index which conceptually links the total grain loss with number of days to harvest after heading. The index is directly proportional to the model

inputs and helped to determine the relative importance of day to harvest after heading (DHAH) as a loss input variable.

3.5.3 Monte Carlos Simulation and Sensitivity Analysis

A triangular probability distribution was selected to model each loss input variables using Argo version 4.1.3 software. A Monte Carlos simulation was used to run each loss input variable. For all simulations, 10000 trials were performed using Latin Hypercube sampling.

The simulation was to help predict the likely levels of grain losses that might occur across the rice farms in the study area when this study is repeated several times, say ten thousand (10000) times. Sensitivity analyses were then performed to assess the relative contribution of each input variable to total paddy loss in the study area.

CHAPTER FOUR

4.0 RESULTS

4.1 Background Information about the Respondents

4.1.1 Demographic Characteristics of respondents

Forty farmers were interviewed in the survey. Majority (80%) of the respondents were males while 62.5% were within the age bracket of 40-59 years. With respect to level of education, basic education was the most attained level (47.5%). Table 4.1 presents the demographic characteristics of the respondents.

Table 4.1. Demographic characteristics of Respondents

Gender	Percentage
Male	80
Female	20
Total	100
Age of farmers	
20-39	35
40-59	62.5
60-79	2.5
Total	100
Educational levels	
No formal	5
Basic	47.5
Secondary	27.5
Tertiary	20
Total	100

Source: Survey data, 2018 Minor Cropping Season, Akatsi North District

4.1.2 Farming Characteristics of Respondents

4.1.2.1 Experience of Respondents in Rice Farming

In general, 80% of the respondents had below 20 years' experience in rice farming (Figure 4.1)

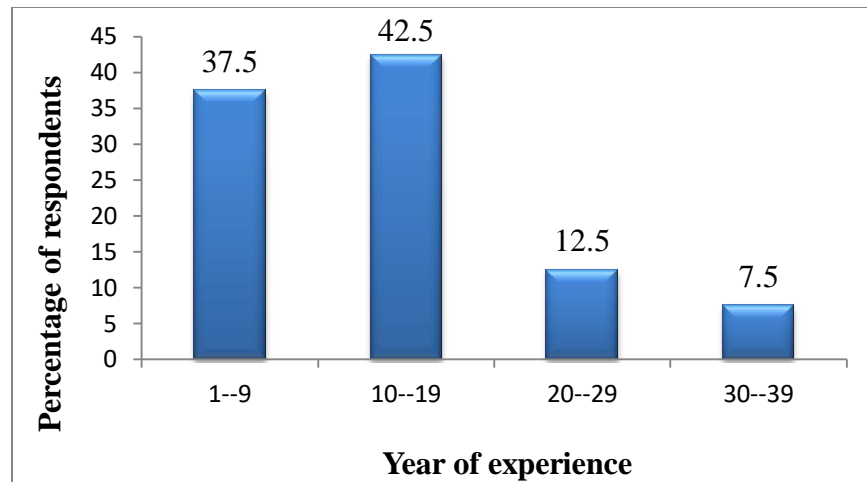


Figure 4.1 Years of Experience of Respondents in Rice Farming

4.1.2.2 Rice varieties cultivated

The most widely cultivated rice variety was Jasmine 85 and was grown by 62.5% of respondents. Togo marshal was cultivated by 20%, 10% cultivated Agra while 7.5% cultivated more than one variety

4.1.2.3 Farm Size and Sources of Labour

The average land area under cultivation was 2 ha. Greater proportion of the respondents (50%) had farm sizes in the range of 0.405- 2.023 ha. The result also indicated that respondents mostly engaged a combination of family and hired labour (40%) for assistance on the farm (Table 4.2)

Table 4.2 Farm Sizes and Sources of Labour for Production

Farm size (acre)	Percentage
<1	5
1-5	50
6-10	25
>10	10
Total	100
Source of labour	
Family	22.5
Hired	37.5
Both	40
Total	100

Source: Survey data, 2018 minor cropping season, Akatsi North District

4.1.2.4 Harvesting and Threshing Methods

The harvesting and threshing methods employed by the farmers are presented in Table 4.3. The commonly used method was manual for harvesting and threshing. The respondents (55%) harvested their crops with sickle, 40.0% used wooden box (bambam) while 12.5% beat the panicles during threshing.

Table 4.3. Harvesting and threshing methods used by rice farmers

Harvesting method	Percentage
Combined harvester	15.0
Manual/ sickle	55.0
Both	30.0
Total	100.0
Threshing method	
Machine	15.0
Box/ Bambam	40.0
panicle beating	12.5
Both	32.5
Total	100.0

Source: Survey data, 2018 minor cropping season, Akatsi North District

4.1.2.5 Estimated Levels of Output at Community Level

Table 4.4 presents the total estimated output of the communities where the study was done. Level of yield was estimated by number of bags (40 kg bag) per hectare. The estimated average output was 62 bags (2480 kg/ha), equivalent to 2.48 Mt/ha. 32.5% of the respondents do harvest 880 -1000 kg/ha, 25% said that yield per hectare was in the range of 1920 - 2880 kg and 42.5% (17) put the yield level of paddy per hectare within the range of 2960 - 3840 kg (Figure 4.2).

Table 4.4 Mean Yields of Paddy at the Community Level

Community	Mean Yield (Mt /ha)
Dakpa	3.410
Agormor	2.530
Havi	2.450
Dzadzefe	2.470
Afiadenyigba	1.420
Total	12.280

Source: Generated from survey data, 2018 minor cropping season, Akatsi North District.

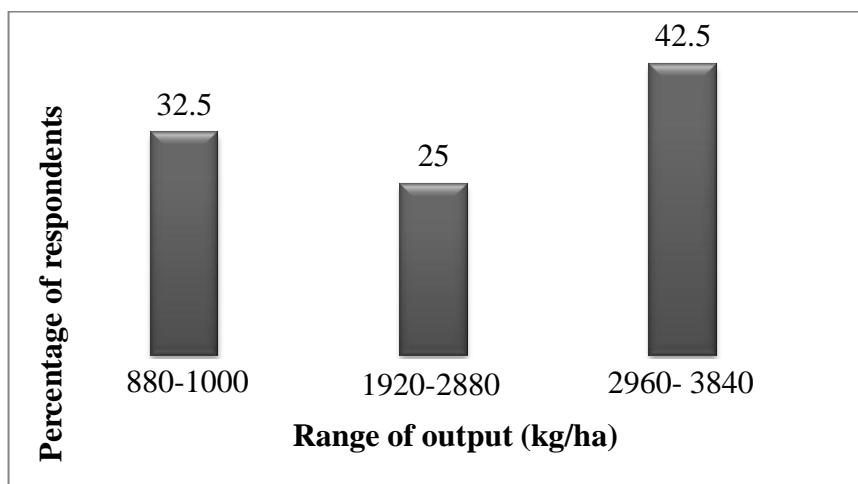


Figure 4.2 Perceived range of output at the community level

4.1.3 Assessment of Knowledge and Perception of Farmers on Postharvest Losses

4.1.3.1 Education on loss assessment

Majority (75%) of farmers interviewed had no access to education on postharvest loss (PHL) assessment of paddy rice. However, a few (25%) of them had some form of education on it. Consequently, losses were guess estimated.

4.1.3.2 Perceived Harvest losses

The maximum perceived harvesting loss (shattering and incomplete cutting) of paddy was 493.8 kg/ha (Figure 4.3). Nevertheless, 45% of the farmers perceived the loss to be 187.5 kg/ha. The average weight loss was 237 kg /ha. The percentage perceived harvest loss of paddy was in the range of 1.67 – 25 and mean value of 9.96%.

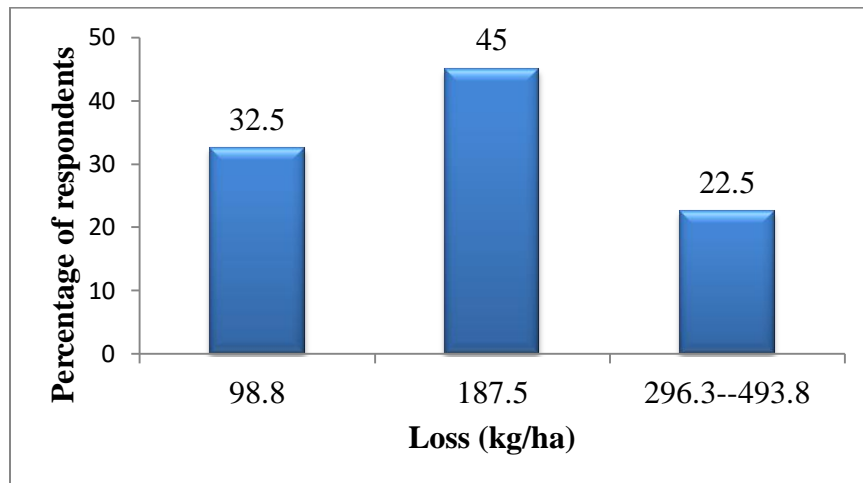


Figure 4.3 Perceived harvesting losses

4.1.3.3 Perceived Threshing Losses

The perception and estimation of respondents on threshing losses is shown in Figure 4.4. Threshing is mostly done by manual method because of its associated low cost. The estimated average threshing loss was 111.6 kg/ha. Forty percent (40%) of the respondents experienced the highest loss 187.5 kg/ha. The percentage yield loss was in the range of 1.38% and 13.33% with an average of 4.72%.

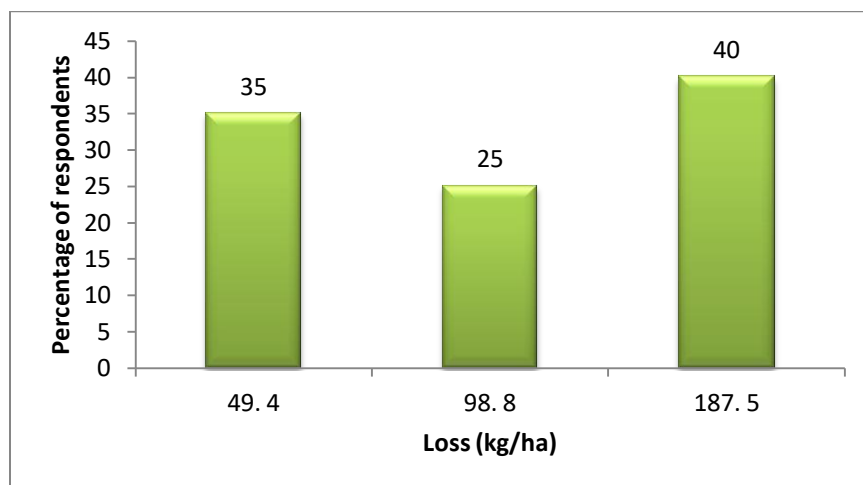


Figure 4.4 Perceived threshing losses

4.1.3.4 Perceived In-Field Stacking Losses

Varied levels of yield losses (49.4 to 493.8 kg /ha) were attributed to in-field stacking (intermediary piling) of paddy in the field (Figure 4.5). Greater proportion (47.5%) of respondents lost about 187.5 kg/ha of grains to the soil when harvested panicle is put in smaller heap on the farm during the manual harvesting process. Five percent (5%) of respondents perceived the loss to be as high as 296.3 to 493.8 kg/ha. The perceived average paddy loss for in-field stacking was 3.08% in the range of 2.0 and 8.0 %,

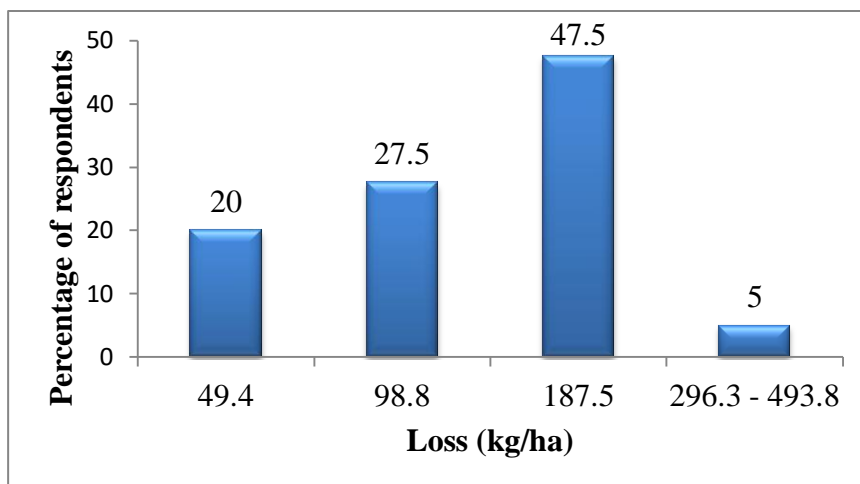


Figure 4.5 Perceived intermediary piling losses

Table 4.5 Summary of Paddy Losses at the Points of Assessment as Perceived by Respondents

Point of loss	% Mean losses
Harvesting	9.96 ± 5.16
Threshing	4.27 ± 2.93
Cleaning	3.08 ± 1.18
In-field Stacking	3.82 ± 1.77

Source: Survey data, 2018 minor cropping season, Akatsi North District.

4.1.3.5 Perception of Farmers on Losses at Farm Level

Majority of the respondents agreed that the losses were large enough to affect their total output (Figure 4.6). The respondents (95%) said the losses were significant for harvesting, 75% perceived threshing loss as large and 90% also agreed that losses due intermediary piling (in-field stacking) were significant. The rest of the respondents, however, thought that the losses were normal, thus insignificant.

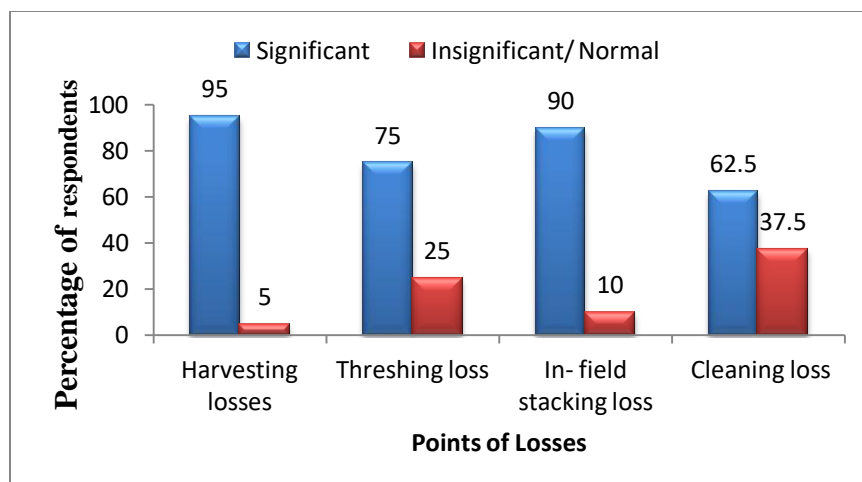


Figure 4. 6 Perception of respondents on the levels of losses

4.1.3.6 The Overall Perceived Average Yield Loss by Respondents

The overall perceived yield loss per hectare in the field was 296.3 kg minimum and 740.7 kg maximum with average loss of 503.7 kg. The percentage yield loss estimated by the respondents was in the range of 12 - 33.3% with the mean value of 21.56% of the total yield.

Table 4.6 Summary of Overall Average Yield Loss Perceived by Respondents

Parameter	Minimum	Maximum	Mean	Standard deviation
Estimated average yield	296.2	740.7	503.7	135.6
Loss (kg/ha)				
Percentage loss (%)	12.0	33.3	21.56	5.7

Source: Generated survey data, 2018 minor cropping season, Akatsi North District.

4.1.3.7 Factors Influencing Losses in the Field and Challenges Encountered by Farmers in the Study Area

The perception of farmers on some factors that influence losses in the field and challenges of farmers were examined and ranked by using a 5-point Likert scale with the Perception indices in Tables 4.7 and 4.8. The mean response scores were determined by the equation $\bar{x} = \frac{\sum xi}{N}$

Tables 4.7 and 4.8. The mean response scores were determined by the equation $\bar{x} = \frac{\sum xi}{N}$

Where, xi = number of individuals who chose the ith response

N = total number of respondents

Weather condition, with the least mean score of 1.6, was generally perceived by farmers to have the greatest influence on loss of rice in the field (ranked 1).

Time of harvesting, however, was perceived as the most important agronomic factor affecting loss of rice in the field (mean score 1.8 and ranked 2).

Access to credit and bird damage⁷⁶ in the field were the most pressing challenges confronting farmers in the study area. Consequently, they were both ranked 1, with the mean score 1.0.

Table 4.7 Perception of Farmers on Factors Influencing Loss of Paddy in the Field

Factors	Mean Score	Ranks (Order of influence)
Weather condition	1.6	1
Time of harvesting	1.8	2
Pests and diseases	2.5	3
Harvesting method	2.7	4
Unimproved seeds	2.9	5
Planting method	3.4	6

Perception indices: Very high -1 High -2 Can't tell -3 Low - 4 Very low - 5

Source: Survey data, 2018 minor cropping season, Akatsi North District.

Table 4.8 Challenges that Farmers Encounter in Rice Production in the Study Area

Challenges	Mean score	Rank (order of most pressing)
Access to credit	1.0	1
Destruction by birds	1.0	1
Extension service	1.5	2
Inadequate labour	2.1	3
Ready market	2.4	4
Tools and equipment	2.5	5
Storage facilities	2.8	6
Access to land	2.9	7
Diseases	3.1	8
Improve seeds	3.3	9

Perception Indices: 1- Very challenging, 2- Challenging, 3- Some times, 4-Less challenging, 5- Not challenging

4.1.3.8 Measures adopted to Reduce Losses at Farm Level

Most of the farmers (67.5%) agreed that losses are greatly reduced when paddy harvesting is timely done and birds and rodents properly controlled (Figure 4.7). Immediate gathering of harvested panicle (15%), use of combined harvester (12.5 %) and planting of good varieties of rice (5%) were also suggested to reduce general paddy losses in the field.

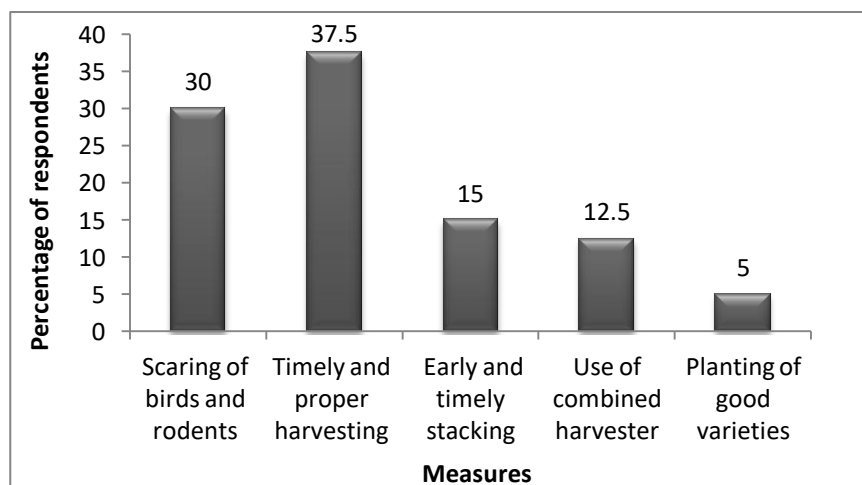


Figure 4.7 Measures adopted by farmers to reduce paddy loss at farm level

4.2 Estimation of Field Losses at 35 Days to Harvest after Heading (35 DHAH) and Farmers’ Actual Days of Harvesting (Variable Days)

4.2.1 Paddy Yield at the Two Different Harvesting Times

The summary of the overall yield for the two different harvesting times is presented in Table 4.9. The study showed that the total yield at the two different harvesting times (35 DHAH and farmers’ practice) was not significantly different at 95% probability. The yield comparison is shown in Figure 4.8.

Table 4.9 Average paddy yield at Recommended Day and the Farmers’ Actual Days for Harvesting

Harvesting times	Minimum (Mt/ha)	Maximum (Mt/ha)	Mean (Mt/ha)	Standard deviation
Recommended practice	2.05	6.09	3.77	1.33
Farmers’ days	1.98	6.11	3.58	1.45

Source: Experimental fields, 2018 minor cropping season, Akatsi North District

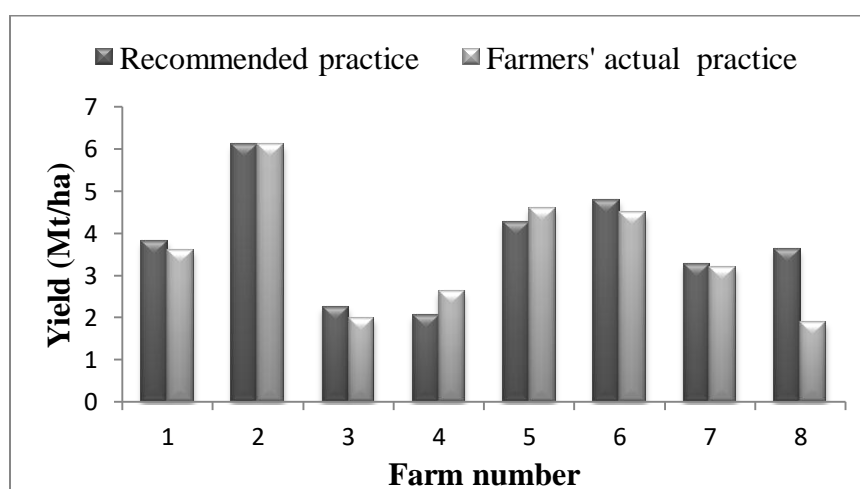


Figure 4.8 Comparisons of paddy yield levels for the two harvesting times at eight farms

4.2.2 Paddy Losses at the Recommended Harvesting Time (35 days to harvest after Heading -35 DHAH)

In order to confirm or challenge the losses claimed by farmers, experiments were conducted in the farmers' fields. The average total paddy yield was 418.88 g/m² of which an average of 22.22 g/m² loss was recorded. The harvesting loss recorded at 35 DHAH was 8.88 g/m² (Table 4.10). This was estimated from shattered grains and matured panicles that were not harvested during the harvesting operation. The estimated loss during harvesting was in the range of 0.99 - 4.44% (Table 4.12) with an average loss of 2.36% (Table 4.11).

The threshing loss was estimated from the intercepted scattered grains and the residual grains on the threshed panicles. The mean weight loss estimated in the experimental field was 8.77 g/m² (Table 4.10). The average percentage threshing loss was 2.06% (Table 4.11) within the range of 1.64 - 3.09%. (Table 4.12).

In-field stacking (intermediary piling) of harvested panicles accumulated an average loss of 5.56 g/m² while cleaning amassed an average loss of 2.22 g/m² (Table 4.10). In general, the losses for in-field stacking ranged from 0.41 – 3.06% (Table 14) with a mean of 1.47% (Table 4.11) whereas cleaning losses were in the range of 0.29 - 0.76% (Table 4.12) and a mean value of 0.56% (Table 4.11). The overall percentage losses for the recommended practice ranged from 4.54 – 8.36%, averaging 6.38% (Table 4.12).

The results showed that losses at cleaning and in-field stacking were not significantly different. However, cleaning and in-field stacking losses were significantly ($p < 0.05$) lower than harvesting and threshing losses.

The contributions of shattered grains, incomplete cutting of panicles, scattered grains and unthreshed grains to harvesting and cleaning losses are presented in Table 4.11.

Table 4.10 Losses at the Four Points of Assessment for Recommended Harvesting Time (35 DHAH)

Treatment	Minimum (g/m ²)	Maximum (g/m ²)	Mean (g/m ²)	Standard Deviation	v.r	F pr
Cleaning loss	1.11	3.33	2.22	1.11	1497.77	<.001
In-field stacking loss	1.11	4.44	5.56	1.11		
Threshing loss	4.44	14.44	7.77	3.33		
Harvest loss	4.44	16.66	8.88	4.44		
Total loss	16.67	32.22	22.22	5.55		
	L.S.D.		2.78			

Source: Generated from experimental field data, 2018 minor cropping season, Akatsi North District

Table 4.11 Contributions of Shattered Grains, Incomplete Cutting of Panicles, Scattered Grains and Unthreshed Grains at Recommended Harvesting Date to Total Grain Yield Loss

Parameters	Yield loss(g/m ²)	Yield loss (%)
Shattered grains	3.33	0.88
Incompletely cut panicles	5.55	1.47
Harvesting loss	8.88	2.36
Scattered grains	3.33	0.88
Unthreshed grains	4.44	1.18
Threshing loss	7.77	2.06
Cleaning	2.22	0.59
In-field stacking	5.56	1.47
Total	22.22	6.38

Source: Experimental field data, 2018 minor cropping season, Akatsi North District

Table 4.12 The Overall Paddy Losses at the Four Major Points of Assessment for Recommended Practice (35 DHAH)

Point of Loss Assessment	Range of Yield Loss (g/m ²)	Range of Yield Losses (%)
Harvest Loss	4.78 – 16.88	0.99 - 4.44
Threshing Loss	3.89 – 13.88	1.64 – 3.09
Cleaning Loss	1.11 - 3.33	0.29 – 0.76
In-field stacking Loss	1.11 – 13.33	0.41 – 3.06
Total Loss	16.66 – 32.22	4.54 – 8.36
	22.22	6.38

Source: Experimental field data, 2018 minor cropping season, Akatsi North District

4.2.3 Losses Associated with the Farmers' Actual harvesting Days (farmers' practice)

The average total paddy yield of farmers' practice was 397.77 g/m² with an average total loss of 24.44 g/m² was recorded (Table 4.13).

The average harvesting loss recorded for the farmers' practice was 10.00 g/m² (Table 4.13). This was a cumulated loss of Shattered grains during harvesting and incompletely cut matured panicles. The estimated loss during harvesting was 1.01% minimum and 7.24% maximum (Table 4.15) with a mean of 2.79% (Table 4.14) of the total yield.

The average threshing loss estimated was 2.79% of the total yield (Table 4.14)..The weight loss attributed to threshing in the experimental field was 10.00 g/m² (Table 4.13). The minimum threshing loss was 1.64% while the maximum was 3.09% (Table 4.15)

The quantity of paddy lost to the soil through in-field stacking of the harvested rice stalks gave an average value of 6.67 g/m² (Table 4.13). The overall loss recorded for in-field stacking of paddy ranged between 0.39 – 2.07% with an average of 1.86% (Tables 4.14 and 4.15).

The grains recovered in the process of cleaning as was 2.56g/m² (Table 4.13). The percentage loss was between 0.45% - 1.15% (Table 4.15) and 0.71% as the mean of the total yield (Table

4.14).. The overall percentage losses for farmers' actual harvesting practices ranged from 4.84 – 13.81%, averaging 7.65%.

From the results, losses at cleaning and in-field stacking were similar to harvesting and threshing losses. However, cleaning and in-field stacking losses were significantly ($p < 0.05$) lower than harvesting and threshing losses.

The contributions of shattered grains, incompletely cut panicles, scattered grains and unthreshed grains to the harvesting and threshing losses are presented in Table 4.14.

Table 4.13 Paddy Loss at the Four Major Points of Assessment for Farmers' Practice

Variables	Minimum (g/m ²)	Maximum (g/m ²)	Means (g/m ²)	Standard Deviation	v.r	F pr.
Cleaning loss	2.22	3.33	2.56	1.11	1655.55	<.001
In-field stacking loss	1.11	4.44	6.67	2.22		
Harvesting loss	5.55	15.55	10.00	3.33		
Threshing loss	4.44	16.66	10.00	3.20		
Total	17.77	35.55	24.44	1.44		
		L.S.D.	3.31			

Source: Experimental field data, 2018 minor cropping season, Akatsi North District

Table 4.14 Relative Contributions of Shattered Grains, Incomplete Cutting of Panicles, Scattered Grains and Unthreshed Grains to Total Paddy Loss (farmers' practice)

Parameters	Yield loss (g/m ²)	Yield loss (%)
Shattered grains	4.44	1.24
Incompletely cut panicles	5.56	1.56
Harvesting loss	10.00	2.79
Scattered grains	3.33	0.93
Unthreshed grains	6.67	1.86
Threshing loss	10.00	2.79
Cleaning	2.56	0.71
In-field stacking	6.67	1.86
Total	24.44	7.65

Table 4.15 Overall Yield Losses at the Four Major Points of Assessment for Farmers' Practice

Point of Loss Assessment	Range of yield Loss (g/m ²)	Range of Yield Loss (%)
Harvest Loss	5.55 – 15.55	1.01 – 7.24
Threshing Loss	4.44 – 16.66	1.64 – 3.09
Cleaning Loss	2.22 – 3.33	0.45 – 1.15
In-field Stacking Loss	1.11 – 11.11	0.39 – 2.07
Total Loss	17.77 – 35.55	4.84 – 13.81
	24.44	7.65

Source: Experimental field data, 2018 minor cropping season, Akatsi North District

4.2.4 Comparison of Source of Paddy Losses for the Recommended Practice, Farmers' Actual Practice and Farmers' Perception

The losses at each of the four main points of assessment for the recommended practice, the farmer's actual practice and the perceived losses of farmers are compared in Table 4.16 and Figure 4.9. The results indicated that paddy losses were not significantly different for recommended practice (35 DHAH) and the farmers' actual practice. However, the perceived losses of farmers were significantly higher ($p < 0.05$) than the estimated paddy losses at the experimental fields for the two harvesting times.

Table 4.16 Overall Paddy Losses at the Four Main Points of Assessment for Recommended Practice Farmers' Actual Harvesting Days and Farmers' Perception

Point of loss	% Mean losses (Recommended)	% Mean losses (Farmers' practice)	% Mean losses (Perceived)
Harvesting	2.36 ± 1.33	2.79 ± 1.33	9.96 ± 5.16
Threshing	2.06 ± 0.55	2.79 ± 1.02	4.27 ± 2.93
Cleaning	0.56 ± 0.19	0.71 ± 0.27	3.08 ± 1.18
In-field Stacking	1.47 ± 0.35	1.86 ± 0.53	3.82 ± 1.77
Overall loss	6.38 ± 4.72	7.65 ± 3.06	21.56 ± 7.31
LSD	3.97		

Source: Experimental Fields Data, 2018 Minor Cropping Season, Akatsi North District

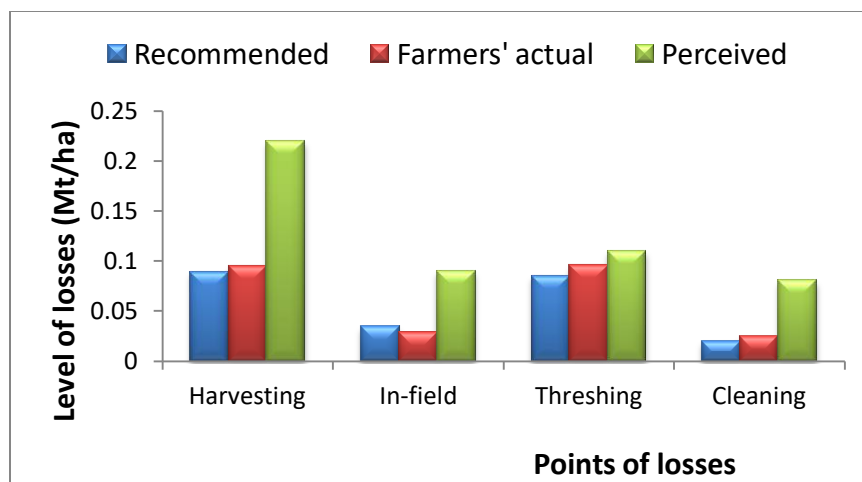


Figure 4.9 Comparison of yield losses for recommended practice, farmers' practice and farmers' perception

4.3 Distributions of Grain Losses and Contributions of Loss Variables to the Total Grain Loss (TGL)

The uncertainty in the input variables that account for the total grain losses incurred by each farmer during field handling of rice required using Monte Carlo simulation models to estimate the probable losses of paddy that occur in the study area. The study measured the following inputs: number of days to harvesting after the rice is headed, Shattered grains loss, incomplete cutting loss, In-field stacking loss, scattered grains loss, unthreshed grains loss and cleaning loss.

The tables and figures presented in this section are the results of ten thousand (10000) trial simulation of the loss input variables with Monte Carlos simulation model using a Latin Hypercube sampling.

Tables 4.17 and 4.18 summarized the simulation results for the two harvesting times. The results showed the mean total grain loss for 35 DHAH was 22.3 g/m² (Table 4.17) and mean total grain loss for farmers' actual practice was 26.9 g/m² (Table 4.18).

Table 4.17 Level of losses after 10000 trial simulation (35 DHAH)

Variable	Minimum (g/m ²)	Maximum (g/m ²)	Mean (g/m ²)	Standard Error (g/m ²)
Days to harvest*	35.000	35	35.000	0.000
Shattered grains	2.005	6.203	3.739	0.009
Unharvested grains	2.939	11.798	6.674	0.019
In-field stacking	1.612	12.571	7.031	0.022
Scattered grains	0.308	1.895	1.170	0.003
Unthreshed grains	0.136	2.207	1.255	0.004
Cleaning	1.785	3.211	2.462	0.003
Total	13.131	33.475	22.332	0.031

Source: Experimental Fields Data, 2018 Minor Cropping Season, Akatsi North District

Days to harvest* is not affected by the unit (g/m²)

Table 4.18 Level of losses after 10000 trial simulation (Farmers' actual practice)

Variable	Minimum (g/m ²)	Maximum (g/m ²)	Mean (g/m ²)	Standard Error
Days to harvest*	33.022	38.970	36.249	0.012
Shattered grains	1.762	6.663	4.171	0.010
Unharvested grains	3.288	11.625	7.090	0.017
In-field stacking	1.762	6.664	9.823	0.010
Scattered grains	1.501	2.555	2.005	1.054
Unthreshed grains	0.114	1.302	0.699	0.002
Cleaning	1.793	4.3140	3.111	0.005
Total	17.0630	21.384	26.900	0.033

Source: Experimental fields data, 2018 minor cropping season, Akatsi North District

Days to harvest* is not affected by the unit (g/m²)

4.3.1 Distribution of Days to Harvest after Heading

The range of days within which rice (Jasmine 85) farmers in the Akatsi North District are likely to harvest their crop after heading is presented in Figure 4.10. The distribution suggested that at 95% probability, rice farmers in the district are likely to harvest their crops between 34.3 and 38.4 days after heading.

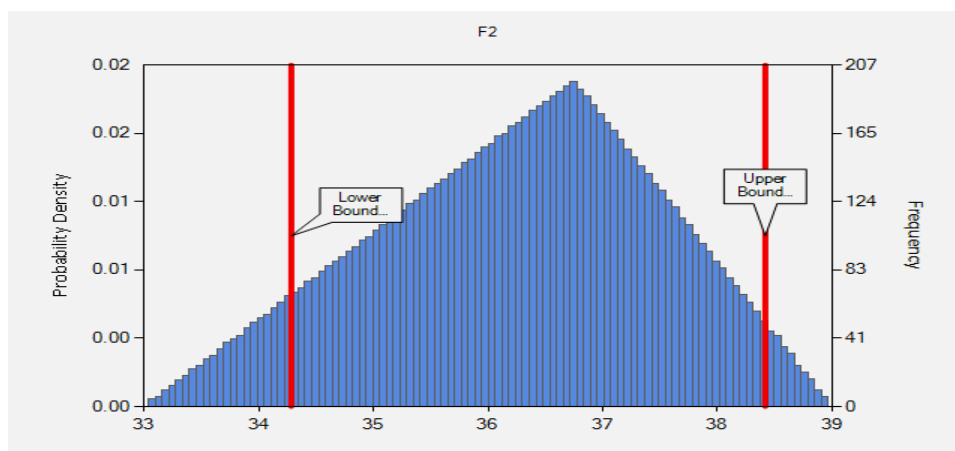


Figure 4.10 Probability distribution of days to harvest after heading at 95% likelihood.

4.3.2 Distribution of Total Grain Loss

The potential range of total grain losses that may occur during harvest and postharvest handling of paddy in the field as a result of variations in the loss input variables across the study area is presented in Figures 4.11 and 4.12. At 95% probability, there is a likelihood that farmers harvesting 35 days after the panicles of their crops are fully visible will experience a total output loss within the range of 15.9 – 28.7 g/m² while the farmers' practice will encounter total losses ranging from 20.3 - 33.4 g/m².

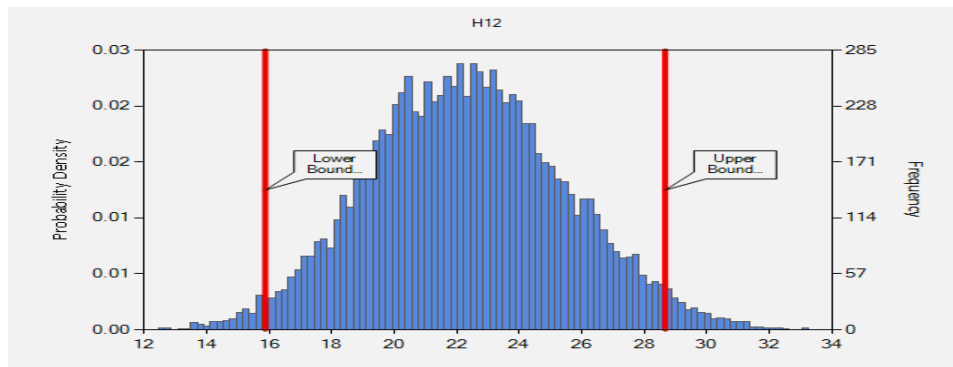


Figure 4.11 Probability distribution of total grain loss at 35 DHAH (95% probability)

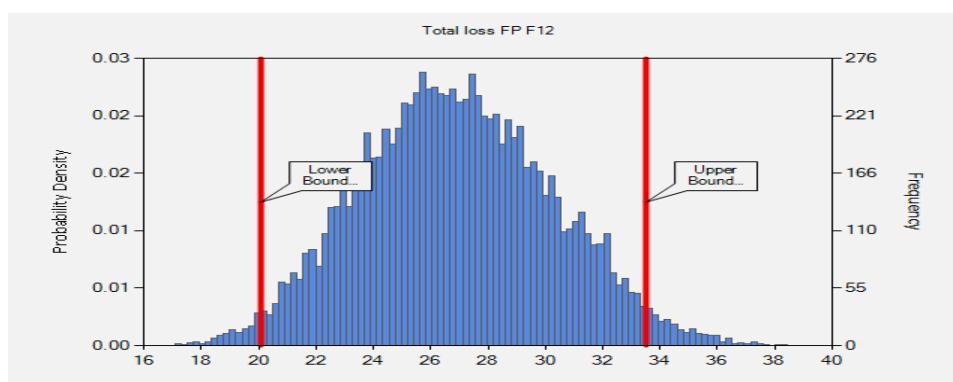


Figure 4.12 Probability distribution of total grain loss for farmers' actual practice (95% probability)

4.3.3 Contributions of the Loss Input Variables to the Total Grain Loss (TGL)

The contributions of the loss variables to the total grain loss are presented in Figures 4.13 and 4.14. The result suggested that the contribution of in-field stacking to the total grain loss of the recommended practice would range from 20.4 – 23.7 g/m² and 24.9 – 28.6 g/m² for the farmers practice as the highest contributor of losses.

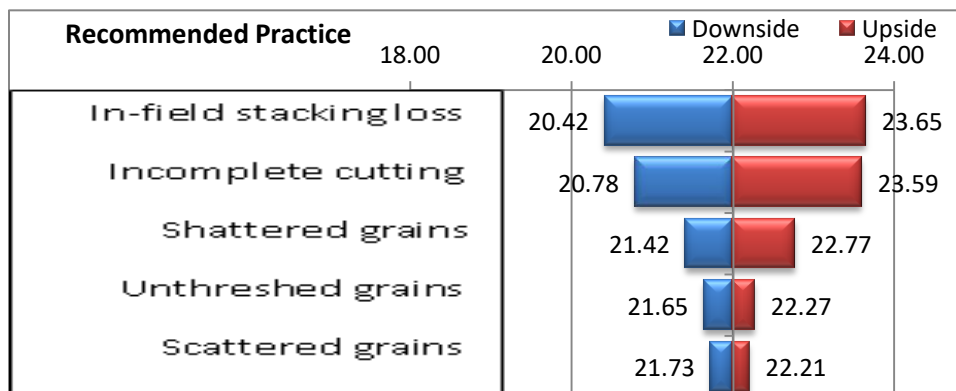


Figure 4.13 Relative contributions of input variables to Total Loss (35 DHAH)

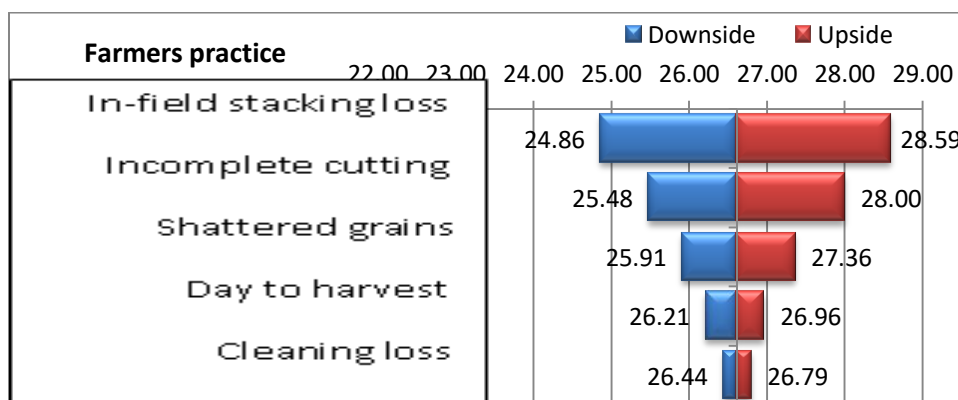


Figure 4.14 Relative contributions of Input Variables to Total Grain Loss (Farmers' practice)

4.3.4 Total Grain Loss. Day (TGLD)

Total Grain Loss. Day Index (I) was created to conceptually link the total grain loss with number of days to harvest after heading. The index was set in a way such that the Total Grain Loss Day (TGLD) is directly proportional to the model inputs.

The effect of number of days to harvest rice (Jasmine) on the loss input variables is presented in Figures 4.15 and 4.16. With the assumption that the losses do not change along with changes in the number of days, farmers harvesting 35 days after heading, for instance, are likely to lose grains through shattering between 749.70 gramday/square metre minimum and 796.91

gramday/square metre maximum whereas grain loss in the practice of the farmers would likely range from 943.14 – 995.87 gramday/square metre.

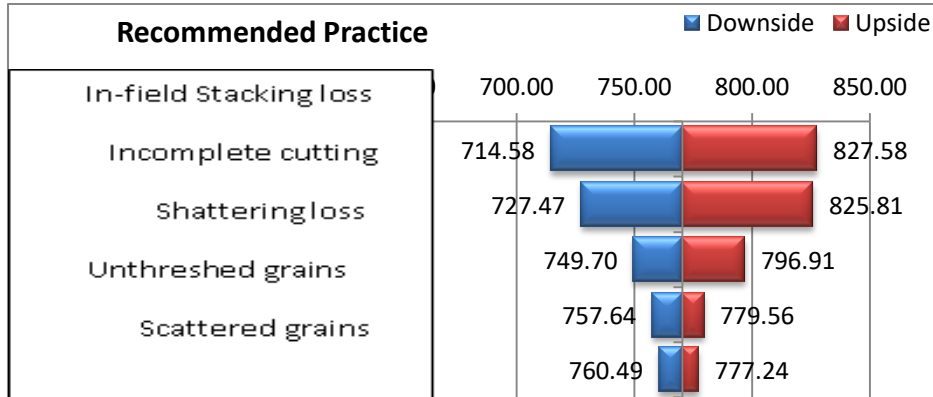


Figure 4.15 Total Loss. Day of the Loss Input Variables (35 DHAH)

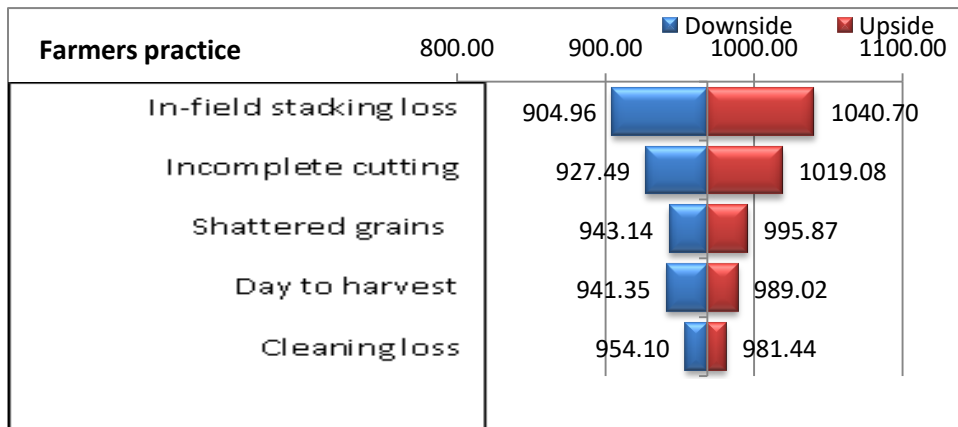


Figure 4.16 Total Loss. Day of the Loss Input Variables (Farmers' practice).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Demographic Characteristics of the Rice Farmers

Majority (90%) of the respondents attained varied levels of formal education, of which basic level (47.5%) was dominant. Only 20% of the respondents attained tertiary level of education. This confirmed the observation made by Yannicke (2016) that educated people are minimally involved in agriculture and this is a threat to the future development of the sector. The fact that most of the respondents have had some level of formal education leverages better understanding the benefits of improved harvest and postharvest technologies. This suggests a higher potential for adopting improved harvesting and postharvest technologies among farmers. With respect to level of experience, only 20% of the respondents have been in rice farming for 20 years and above. This implies there is the need to increase access to improved technologies of harvest and postharvest handling to enhance farmers experience and productivity.

5.1.2 Knowledge and Perception of Farmers about Harvest and Postharvest Losses of Rice

The survey revealed that farmers were aware of paddy losses that occur at the various stages of postharvest handling of paddy rice at the farm level. However, majority have not been given any formal education or training on determination of the level of losses that occur. Seventy five percent (75%) of the respondents never had any training on PHL estimation. The losses are, therefore, guess estimated using experience. These findings confirmed the results of similar work done by Nketia (2015). At least 60% of farmers perceived paddy losses that occur at various points of assessment at the farm level as significant. This implies that greater proportion of the farmers might be more willing to accept improved techniques for reducing postharvest losses at the farm level. An intensive agricultural extension education on postharvest loss at farm level is,

however, important to enhance the knowledge of farmers in postharvest loss estimation. The perceived harvesting losses ranged from 1.6 - 25% with average value of 9.96% of total yield. This was close to 12.05% perceived harvesting losses reported on some farmers' fields in Ghana (GUISSE, 2010).

Threshing was manually done by majority (52.5%) of the farmers. This was due to the high cost associated with mechanical harvesting and threshing and inadequate equipment, according to the respondents. Manual threshing method is also popular among farmers for the reason that it is less expensive. The observation is confirmed by Rickman *et al.* (2013). The authors, however, observed that quantitative and qualitative losses can be as high as 20-30%.

The high level of losses reported might be due to the slow pace at which threshing a unit mass of paddy manually is accomplished and the energy required to do so. Amposah *et al.* (2018) in evaluating manual and mechanical threshing methods indicated that manual method required 834 watts of power to thresh 64.9 kgh⁻¹ while mechanical method required 660 watts of power to thresh 158.4 kgh⁻¹

The perceived threshing loss by the respondents was within the range of 1.38 – 13.33%, averaging 4.72%. This result is lower than the 25% threshing loss perceived by rice farmers in Uganda (Ssebagala *et al.*, 2017).

In-field stacking (intermediary piling) and cleaning losses were perceived as 3.82% and 3.08% respectively. The farmers' overall estimated losses were in the range of 12- 33.3% with a mean of 21.6%.

Losses encountered by farmers in the field of production were perceived to be influenced by weather conditions and some agronomic factors. With least mean score of 1.6, weather condition

was ranked as the most influential factor in field losses of rice. The perception of the respondents was in agreement with the findings of various research works carried out on the effects of weather on yield and quality of rice. Ziska and Bunce (1998) noted that higher minimum temperature reduced the output of rice due to higher loss of carbon through increased respiration. Higher day and night temperatures were also noted by Fitzgerald and Resurreccion (2009) to increase chalkiness in rice which increased grain breakages during dehulling and polishing. Irregular rainfall, rise in temperature, flooding and droughts were further identified by Intergovernmental Panel on Climate Change (IPCC) to reduce rice and wheat production by 8 and 23% by the year 2050 (Cancelliere *et al.*, 2007) cited by Rahman *et al.*(2017)

Time of harvesting, with the mean score of 1.8 was the agronomic factor perceived to have greater effect on loss of rice in the field. Harvesting earlier than recommended causes higher percentage of under-developed green kernels and low head rice recovery (Singh *et al.*, 2000). High shattering losses and attack of crop by birds and rodent occur when harvesting is done late (Baloch, 2010). Thus, timely harvesting is very crucial for yield and quality maximization. Maximum head rice recovery (HRR) was recorded when the rice crop was harvested at 35 days after 50% flowering (Chaudhary and Iqbal. 1986). Therefore, it is right for majority (37.5%) of the respondents to suggest timely and proper harvesting as a measure to reduce losses. The suggestion of the respondents has also agreed with the results of the field experiment conducted in this study which indicated that harvesting at the recommended time (35 DHAH) could generally help reduce losses in the field by 1.27%.

Rice farmers are faced with a wide range of challenges, consisting of biotic and abiotic factors. The numerous challenges may have similar effects of causing physical loss of rice and reduction of farmers' income. Birds, among the biotic factors, are noted to be important pests after weeds

hindering the production of rice in Africa (Global Rice Science Partnership) cited by IRRI *et al.* (2010). A damage of 13.7% to rice in West Africa (Manikowski, 1984) and a loss of \$2.8 million per year (de Mey and Demont, 2013) in Nigeria. The level of losses and damage reported by the various studies and the labour and time required for scaring birds in rice field are consistent with the perception of the farmers on birds as one of the most pressing challenges they encounter.

The overall perceived harvest and postharvest field losses of rice by farmers in the Akatsi North district were in the range of 12.0 – 33.3%. The perceived losses concurred with the 20-30% losses reported by Rickman *et al.* (2013).

5.2 Experimental Field Losses for the Recommended Practice and Farmers' Actual Practice

5.2.1 Harvesting Loss

The loss at harvest comprised the losses due to shattering of grains and panicles that were not cut during the harvesting operation on the demarcated plot. The harvesting loss estimated for the recommended practice (35 DHAH) ranged from 0.99% - 4.44% with an average loss of 2.36%. The farmers' actual practice recorded average harvesting loss of 2.79% and a range of 0.01% - 7.24%. These findings were not far from the result of similar research conducted on NERICA by GUISSÉ (2010). The author found that harvesting losses was between 1.13% and 3.25%. He further reported that IRRI (1997) recorded harvesting losses of 1-3% in South East Asia.

The experimental results indicated that the average harvesting loss for the recommended practice was not significantly different from the average loss for the farmers' actual practice at 5% probability level. The losses produced by shattering of grains for recommended and farmers' practices were also not different at 5% probability level. The rice harvested at 35 days after

heading recorded average loss of 0.88% through shattering of grains. This is at variance to 0.44% shattering loss estimated at 35 day to harvest after heading (DHAH) by Nketia (2015). The estimated shattering loss for farmers' practice in the study was 1.24%. This was not close to the 1.56% and 1.96% shattering loss of Jasmine 85 recorded by Candia *et al.* (2012) and Nketia (2015) respectively for farmers who harvested their rice 42 days after heading..

The results suggest that the duration plant remains in the field might affect the level of shattering. The matured panicles that were not cut at harvesting were observed to contribute greater proportions of 1.18% and 1.86%, respectively for recommended practice and farmers' practice, to total harvesting loss. Despite the insignificance of losses, harvesting rice at the recommended number of days after heading (35 days) will averagely reduce loss of yield by 0.44% compared to farmers' actual days of harvesting.

5.2.2 In-field Stacking Loss

The intermediary piling of harvested panicles in smaller heaps (in-field stacking) also resulted in some amount of losses through grain shedding. The loss estimated for the in-field stacking (heaping) at 35 DHAH ranged between 0.41%- 1.51% while that of farmers' actual practice was in the range of 0.39% -1.85 %. The result showed that the loss at 35 DHAH was not significantly different from the farmers' actual loss at 95% probability level. The mean in-field stacking loss for the recommended practice (35 DHAH) was 1.47% of the output 3.76 Mt/ha, whereas the farmers' actual practice recorded 1.86 of the output 3.58 Mt/ha. These results were within the range of 0.53 – 4.07% estimated by Appiah *et al.* (2011).The losses recorded in this study were also closely related to 2% - 6% loss experienced by Philippines (FAO, 2007).

5.2.3 Threshing Loss

The threshing loss recorded in the field experiment was as a result of scattered grains and residual grains on the threshed straw (unthreshed grains). The threshing loss for the recommended practice ranged between 0.14 – 3.06% with an average of 2.06%, while that of the farmers' practice ranged between 1.64 – 3.09% with an average of 2.79%. In 2007, FAO recorded threshing loss in the range of 5% - 13% in Malaysia. Appiah *et al.* (2011) also reported 6.14% threshing loss for NERICA with box method. The results for this research were, however, lower than the results of FAO (2007) and Appiah *et al.* (2011).

The contributions of scattered grains and residual (unthreshed) grains to the threshing loss for the recommended practice were 0.88% and 1.18% respectively and 0.93% and 1.86% respectively for farmers' actual practice.

The results from the experimental fields showed that the overall losses associated with harvesting and handling paddy rice (Jasmine 85) in the recommended practice ranged from 4.54% to 8.36% with an average of 6.38% whereas the estimated total loss in the farmers' actual practice was in the range of 4.75% to 13.64% and gave an average of 7.65%. The outcome of the study suggested that harvesting at the recommended time (35 DHAH) could generally help reduce losses in the field by 1.27%. A study conducted in India by Kannan *et al.* (2013) estimated an increase in loss of paddy from 1.74% to 1.92% as a result of delayed harvesting caused by lack of adequate harvesting equipment.

Thus, harvesting Jasmine 85 at recommended number of days after heading (35 days) has the tendency of reducing losses at the farm level. Too early harvesting, however, might result in rice grains with high moisture content, leading to high cost of drying, susceptibility to mold growth,

insect infestation, high amount of broken grains and low milling yields likewise, delayed harvesting might also result in high shattering losses (Khan, 2010).

5.3 Contributions of Loss Input Variables to the Total Grain Loss (TGL)

The simulation was performed to predict the level of grain loss each loss variable could contribute to the TGL. The distribution of DHAH (95% probability) indicated that harvesting of Jasmine 85 variety will likely be done 34.3-38.4day after heading in the study district This further suggests that farmer in the district will averagely harvest their crop 36 DHAH, which is closely related to the recommended 35 DHAH .Salim and Sagar (2003) noted that harvesting rice at 33-39 days after 50 % flowering gave significantly higher head rice recovery than 27-30 days or 42 days after flowering. The distribution, thus, implies that rice farmers in the study area are likely to record higher head rice yield (HRY) with respect to day to harvest after heading

Total grain loss likely to be experienced by farmers harvesting at the recommended 35 days after heading is between 15.9 and 28.7 g/m² while those harvesting at their own time are likely to experience total grain loss in the range of 20.3 – 33.4 g/m². The modeling results were not so different from 16.66 – 32.22 g/m² and 17.77 – 35.55 g/m² recorded in the field experiment for the recommended and the farmers' practice respectively. The modeling, however, suggested that rice (Jasmine 85) farmers with their own practices may experience a slight increase in total average grain loss from 24.44 g/m² to 26.90 g/m² while total average grain loss for the recommended practice (35 DHAH) may remain unchanged (22.22 g/m²). .

The sensitivity analysis of the loss input variables suggested that the top three contributing variables were the same for both the recommended practice and the farmers' actual practice but with different levels of losses. The analysis showed that in-field stacking; incomplete cutting of panicles and shattering of grains were the top three contributing variables to the TGLs for both harvesting times. In-field stacking was, however, identified as the input variable likely to contribute the highest loss of 20.42 – 23.65 g/m² and 24.86 – 28.59 g/m² to the TGLs for recommended practice and farmers' actual practice respectively. This analysis agreed with the results of the field experiment which recorded in-field stacking as the most loss contributing variable, accounting for 5.56 g/m² for the recommended practice and 6.67 g/m² for the farmers' practice. However, grain shattering was not identified in the field experiment as one of the top three loss contributing factors as suggested by the sensitivity analysis, rather unthreshed grains for both practices.

The possible losses occurring during in-field stacking could be reduced through adoption of simple technologies such as use of wheel barrows and trailers to collect the harvested panicles directly during harvesting so as to retrieve dropped grains that might have been lost if the panicle were placed directly on the soil.

Total Grain Loss. Day Index (I) was created to conceptually link the total grain loss with number of days to harvest after heading. With the assumption that the losses do change along with changes in the number of days, farmers harvesting 35 days after heading, for instance, are likely to lose grains through shattering between 749.70 gram day/square metre minimum and 796.91 gram day/square metre maximum whereas the farmers' time of harvesting would likely result in grains in the range of 943.14 – 995.87 gram day/square metre.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

- Rice farmers in the study area were aware of the postharvest losses that occur in handling rice in the field but majority (75%) had no access to education on postharvest loss (PHL) assessment of paddy rice. Losses were therefore, guess estimated based on number of bags. At least 60% of farmers agreed that the losses at the various points of handling were large enough to reduce their total output.

The total field loss estimated by farmers was 21.6% with harvesting perceived as the point of handling where the highest loss (9.96%) occurred which was confirmed by the field experiment, suggesting that the farmers perception was close to the actual. The perceived losses of farmers were, however, higher than the field results at all the four points of loss assessment.

- The average yield for the recommended harvesting time (35 DHAH) was 3.77 Mt/ha while that of farmers' practice was 3.58 Mt/ha.

The yield loss at the recommended time (6.38%) was relatively lower than farmers' actual loss (7.65%). The field quantitative loss estimation showed that there was no difference between yields and total losses of the two times of harvesting.

- Sensitivity analysis of loss variables indicated that in-field stacking; incomplete cutting and shattering of grains were the top three input variables contributing to the total loss of grains. However, in-field stacking was identified as the variable likely to contribute most to the total grain loss of rice across the farms in the district.

6.2 Recommendations

- Large sample size for the field verification experiment could not be used in this work due to irregular rainfall pattern. It is recommended that a lot more rice farmer fields be included in subsequent studies to give a clearer trend of losses across the farms in the study area.
- It is further recommended that the study is repeated using more than one rice variety in order to have a fair idea of the level of losses that at the various points of handling in the field.

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APPENDICES

APPENDIX I: QUESTIONNAIRE ON QUANTITATIVE LOSS ASSESSMENT DURING POSTHARVEST HANDLING OF PADDY RICE IN AKATSI NORTH DISTRICT OF VOLTA REGION.

This research is an academic exercise and all information shall be used solely for the purposes stated. Every information given will be treated as confidential.

Section 1 A. General Information about the Farmer

1. Age:
2. Gender: Male Female
3. Marital status: Single Married Divorce Others
4. Highest level of education attained: No formal education Basic Education
Secondary Education Tertiary Education

Section 1B : Farming Characteristics of Respondents

5. how long have you been growing rice farming?..... (Years)
6. Do you do any other kind of work other than farming? Yes No
7. If yes, please specify.
8. Do you usually have any form of assistance on your farm? Yes No
9. If yes, is it family or hired or both
10. What is the size of your farm? Less than 1 acre 1-5 acres 6-10 acres
bigger than 10 acres
11. What variety of rice do you grow? Please specify -----
12. What method of planting do you use? Broadcasting Transplanting Both
Others
13. Do you usually use any agrochemicals during production? Yes No
14. If yes, what type(s) of chemicals are used? -----

15. How long does it take the rice from heading to harvesting? 20-25 days 26-30 days
 31-35 days 36-40 days
16. Which harvesting method(s) do you usually use? Combined harvester manual / sickle
 Both

17. What is your average total harvest (bags) per acre in a cropping season? -----

Section 2: Knowledge, Perception and Experience of Farmers in Loss Assessment.

18. do you usually experience losses on your farm? Yes [] No []

Have you received any training in loss assessment? Yes [] No []

19. If yes, specify the area(s) of training-----

20. In your opinion would you say the training(s) was/were necessary and helpful in increasing your output? Yes [] No []

Loss Assessment at Farm Level

A: Harvesting loss and its estimation

21. Do you usually experience losses during harvesting? Yes [] No []

22. If yes, in which forms do the losses occur? Please explain. -----

23. Do you think the loss is large enough to reduce your expected yield? Yes [] No []

24. If yes, by how many bags in your estimation? Less than 1 bag [] 1 bag [] 2 bags []
3-5 bags [] more than 5 bags []

25. How do you estimate the losses during harvesting? -----

26. What have you done to reduce the harvesting losses? Please specify. -----

B: in-field stacking loss

27 where do you usually place harvested straw during harvesting
?.....

28. how long do you keep the harvested panicles in the field before gathering it to the threshing floor?.....

29. do you usually lose some rice grains when the harvested straws are place in smaller heaps in the field? Yes [] No []

30. In which form do the losses occur?.....

31 Are the losses large enough to affect your output? Yes [] NO []

32. How much ? Half a bag [] 1 bag [] 2 bags 3 bags []

33. How do measure the loss?.....

34 the what do you do to reduce loss ?.....

C: Threshing loss and its estimation

31. What method of threshing do you usually use? Machine [] Manual/ hand [] Both []

If manual,

32 which method? Box or bambam [] Drum [] beating panicles with stick [] others []

33. How long do you usually keep the harvested straw before threshing? Immediately [] 1-3 days [] 4- 7 days [] more than 7 days []

34. what tools, equipment and materials do you usually during threshing?-----

35. Do you experience losses during threshing? Yes [] No []

36. If yes, in which forms do the losses occur? -----

37. In your view are the losses large enough to reduce your total expected output? Yes [] No []

38. If yes, by how many bags? Less than 1 bag [] 1 bag [] 2 bags [] 3-5 bags [] more than 5 bags []

39. How do you measure losses during threshing? Please explain-----

40. In which other ways do losses occur on your farm? -----

41. What have you done to reduce the losses on your farm? Please specify -----

D; Cleaning Loss

42. Do you usually experience losses during cleaning? Yes [] No []

43. how much per acre? 1 bag [] 1 bag [] 2 bags []

44 how do you determine the loss at cleaning

D: Factors Influencing Losses

38. Rank these factors according to the degree of losses caused using the scale provided by putting a tick in the appropriate column in the table

Scale: 1= very high 2= high 3= can't tell 4= low 1 2 3 4 5

5=very low

Weather conditions

Unimproved seeds/varieties

Planting methods

Pests and diseases

Time of harvesting

Harvesting methods

Inadequate labour

Section 3: Challenges

39. On numerical scale of 1 to 5, rank the following as 1- most challenging 2-more challenging 3-some times 4- less challenging 5- Not challenging

1 2 3 4 5

Access to land

Access to credit

Access to tools and machines

Access to improved seeds/ varieties

Destruction of panicles by birds

Diseases

Access to storage facilities

Lack of ready market

Access to extension services/ agricultural education

APPENDIX II: TABLES

HARVEST LOSS AT 35DAYS AFTER HEADING (35DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average Weight of Unharvested and Shattered Grains (kg/9m ²)	Average Total Yield for a Quadrat (Kg/9m ²)	Harvest Loss (%)
1	3.135	0.152	3.287	4.6
2	5.235	0.066	5.301	1.2
3	1.845	0.060	1.906	3.1
4	1.700	0.072	1.772	4.0
5	3.670	0.055	3.72	1.5
6	4.120	0.043	4.163	1.0
7	2.765	0.072	2.017	3.6
8	3.03	0.120	3.15	3.8

IN-FIELD STACKING LOSS AT 35 DAYS AFTER HEADING (35DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average Weight. of In-Field Stacking Losses (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	In-Field Stacking Loss (%)
1	3.135	0.014	3.164	0.4
2	5.235	0.044	5.278	0.8
3	1.845	0.027	1.827	1.5
4	1.700	0.028	1.728	1.6
5	3.670	0.038	3.708	1.0
6	4.120	0.029	4.149	0.6
7	2.765	0.024	2.039	1.2
8	3.03	0.032	3.062	1.0

THRESHING LOSS AT 35DAYS AFTER HEADING (35DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average Weight of Unthreshed and Scattered Grains (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	Threshing Loss (%)
1	3.135	0.143	3.278	4.4
2	5.235	0.148	5.383	2.7
3	1.845	0.063	1.588	3.9
4	1.700	0.042	1.742	2.4
5	3.670	0.069	3.798	1.8
6	4.120	0.091	4.211	2.2
7	2.765	0.069	2.834	2.5
8	3.03	0.065	3.095	2.1

CLEANING LOSS AT 35 DAYS AFTER HEADING (35DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average Weight of Cleaning Loss (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	Cleaning Loss (%)
1	3.135	0.023	1,48	0.01
2	5.235	0.029	5.261	0.6
3	1.845	0.019	1.864	1.0
4	1.700	0.027	1.727	1.6
5	3.670	0.019	3.689	0.5
6	4.120	0.031	4.151	0.7
7	2.765	0.020	2.705	0.7
8	3.03	0.019	3.049	0.6

HARVEST; LOSS OF FARMERS' PRACTICE (37DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average Weight of Unharvested and Shattered Grains (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	Harvest Loss (%)
1	2.91	0.138	3.018	4.6
2	5.23	0.056	5.286	1.1
3	1.625	0.064	1.680	3.8
4	2.19	0.051	2.241	2.2
5	3.995	0.10	3.095	3.2
6	3.825	0.069	3.094	2.2
7	2.67	0.083	2.753	3.0
8	1.535	0.129	1.664	7.8

IN-FIELD STACKING LOSS FOR THE FARMERS' PRACTICE (37DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average. Weight. Of In-Field Stacking Loss (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	In-Field Stacking Loss (%)
1	2.91	0.017	2.927	0.5
2	5.23	0.033	5.56	0.5
3	1.625	0.01	1.636	0.6
4	2.19	0.037	2.227	1.7
5	3.995	0.032	4.027	0.7
6	3.825	0.016	3.841	0.4
7	2.67	0.027	2.697	1.0
8	1.535	0.033	1.568	2.1

THRESHING LOSS FOR THE FARMERS PRACTICE (37DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (Kg/9m ²)	Average Weight of Threshing Loss (Kg/9m ²)	Average Total Yield for a Quadrat (Kg/9m ²)	Threshing Loss (%)
1	2.91	0.143	3.049	4.5
2	5.23	0.148	5.370	2.8
3	1.625	0.063	1.688	3.7
4	2.19	0.042	2.232	1.9
5	3.995	0.069	4.064	1.7
6	3.825	0.091	3.916	2.3
7	2.67	0.069	2.739	2.5
8	1.535	0.065	1.60	4.1

CLEANING LOSS OF THE FARMERS PRACTICE (37DAH)

Farm Number	Average Weight of Threshed Paddy for a Quadrat (kg/9m ²)	Average. Weight. of Cleaning Loss (kg/9m ²)	Average Total Yield for a Quadrat (kg/9m ²)	Cleaning Loss (%)
1	2.91	0.023	2.933	7.8
2	5.23	0.029	5.259	5.5
3	1.625	0.019	1.622	1.2
4	2.19	0.027	2.217	1.2
5	3.995	0.019	4.014	2.3
6	3.825	0.031	3.85	8.1
7	2.67	0.020	2.87	6.6
8	1.535	0.019	1.554	1.2

PERCENTAGE FIELD MOISTURE CONTENT AT HARVEST (%MC)

Farm Number	Recommended [Ractice(35DAH) %MC	Farmers's Practice (37DAH) %Mc
1	15.6	15.3
2	17.4	14.3
3	11.9	11.8
4	13.0	11.6
5	17.3	17.4
6	18.0	17.1
7	16.4	15.9
8	16.9	14.8

COMPARISON OF OUTPUT 35DAH AND 37DAH

Sample	Size	Mean	Variance	deviation	of mean
35DAH_mt_ha	8	3.765	1.762	1.327	0.4693
37DAH	8	3.554	2.098	1.448	0.5121

Difference of means: 0.211

Standard error of difference: 0.695

95% confidence interval for difference in means: (-1.278, 1.701)

Test of null hypothesis that mean of 35DAH_mt_ha is equal to mean of 37DAH

Test	statistic	t	=	0.30	on	14	d.f.
Probability			=				0.765

COMPARISM OF LOSSES AT THE FOUR POINTS OF ASSESSMENT

Losses at 35DAH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	5	202.318	40.464	9.10	<.001
Residual	42	186.800	4.448		
Total	47	389.117			

Loss at Farmers' Practice

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	5	201.609	40.322	8.88	<.001
Residual	41	186.095	4.539		
Total	46	387.705			