

**ESTIMATION OF QUANTITATIVE LOSSES OF RICE (*ORYZAE SATIVA* L.)
DURING HARVESTING, THRESHING AND CLEANING IN THE UPPER
EAST REGION: A CASE STUDY AT TONO IRRIGATION PROJECT**

BY

OFORI OBENG NKETIAH

(10279647)

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

I, Ofori Obeng Nketiah declare that except of references cited, which have been duly acknowledged, this work “**Estimation of Quantitative Losses of Rice (*Oryzae sativa* L.) during harvesting, threshing and cleaning in the Upper East Region: A Case Study at Tono Irrigation Project**” is the result of my own work as a student of the Department of Crop Science, College of Basic and Applied Science, University of Ghana during the 2014 - 2015 academic year. This work has never been presented in whole or part for the award of any degree of this University or elsewhere.

..... Date.....
Ofori Obeng Nketiah
(Student)

This thesis has been submitted for examination with our approval as supervisors

..... Date.....
Prof. P. N. T. Johnson
(Major Supervisor)

..... Date.....
Dr. (Mrs) Gloria Essilfie
(Co-supervisor)

ABSTRACT

Loss assessment helps to identify constraints affecting the production and therefore the productivity of food crops. Information on loss assessment will thus assist in possible interventions needed to improve productivity. Quantitative losses associated with the production of rice (var. *Jasmine 85*) in the Kassena Nankana West District of the Upper East Region, one of the major rice producing areas in Ghana has not been adequately documented. A semi structured questionnaire was used to collect data from 84 rice farmers who were selected through a combination of multi-stage, purposive, and simple random sampling techniques. A multiple regression analysis was conducted to estimate quantitative losses and the factors that influenced the losses of rough rice. Kendall's Coefficient of Concordance (W_C) was used to determine the degree of agreement in the challenges farmers face at farm level. A technology-verification experiment was conducted on 12 farmer fields to estimate the yields and quantitative losses that do occur during harvesting and threshing at two (2) different harvesting times: improved harvesting time (35 days after heading) and farmer time of harvest (42 days after heading). A methodology adopted by Anwar (2010) was used to determine farmers' harvest moisture content of rough rice. Rice cultivation on the Tono Irrigation Project was found to be dominated by males; only 38% were females. Therefore, males have purposefully made rice farming as a livelihood. Averagely, 0.68 ha field was under rice cultivation. Still, the average rough rice was produced at 2.73 mt/ha. The output saved for household consumption (0.7 mt/ha) was not significantly different ($P>0.05$) from the output (0.65 mt/ha) lost to the soil. Besides, the amount of rough rice that could have been saved for domestic consumption was equally lost at a percentage loss of 24%. From the perspective

of the farmers, the losses were attributed to inappropriate time of harvesting. From the regression analysis, acreage ($\beta=0.952$ mt, $P<0.01$) and gender ($\beta=0.162$ mt, $P\leq 0.05$) were found to be positively related with losses in rough rice production. However, farm education ($\beta= -0.656$ mt, $P<0.01$) and adequate labour ($\beta= -0.018$ mt, $P<0.05$) were found to reduce field losses. The coefficient of determination (R^2) was 0.655; which implies that 66% of the variation in the quantity of rough rice lost during harvesting and handling was explained by the specific variables in the model. The F-statistic was found to be significant at 1%. This implies that all the explanatory variables had a significant joint impact on the level of rough rice lost during harvesting and handling. The Kendall (W^a) was estimated at 0.839. This suggests that the degree of agreement among the rankings of the challenges faced at farm gate was approximately at 84%. Therefore, the most pressing challenge was inaccessibility of tarpaulin and continuous adoption of improvised tarpaulins. From this study, the yield from improved time of harvest (4.8 ± 0.96 mt/ha) was ($P<0.05$) higher than farmer time of harvest (3.7 ± 1.2 mt/ha). Therefore, the losses incurred during improved harvest ($5.88 \pm 3.47\%$) was lower than farmer time of harvest ($10.35 \pm 1.94\%$). The harvest moisture content ($20.88 \pm 2.56\%$) was not significantly different ($P>0.05$) from the optimum harvest moisture content (22%). Increasing loss reduction awareness through farmer field schools and farmers adopting 35 days after heading as a harvesting time could lessen high levels of field losses, poverty index and improve domestic consumption.

DEDICATION

I would like to dedicate this thesis to my father Mr. Kwagyan Ofori, and my mother Ms. Beatrice Koduah for their prayers, encouragement and financial support.



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LIST OF ABBREVIATIONS

CARD	Coalition for African Rice Development
CBOs	Community Based Organizations
CRI	Crop Research Institute
CSA	Commodity System Assessment
CSIR	Council of Scientific and Industrial Research
DAH	Days After Heading
FAO	Food and Agriculture Organization
FBOs	Farmer Based Organizations
FFSs	Farmer Field Schools
GAPs	Good Agronomic Practices
GSFP	Ghana School Feeding Programme
HMC	Harvest Moisture Content
HRY	Head Rice Yield
ICOUR	Irrigation Company of Upper Region
IFAD	International Fund for Agricultural Development
IRRI	International Rice Research Institute
LDCs	Less Developed Countries
MCs	Moisture Contents

MiDA	Millennium Development Authority
MOFA	Ministry of Food and Agriculture
PHH	Postharvest Handling
PHLs	Postharvest Losses
R^2	Adjusted Coefficient of Determination
SARI	Savannah Agriculture Research Institute
SRID	Statistical Research Institute Department
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
Var.	Variety
w.b	Wet basis
W^a	Kendall
WARDA	West Africa Rice Development Association
W_C	Kendall's Coefficient of Concordance

CHAPTER ONE

1.1 INTRODUCTION

Rice (*Oryza sativa* L.) is a prime cereal crop for about 40 per cent of the world's population (Bhullar & Gruissem, 2013; Jackson & Lettington, 2003; Khush & Brar, 2002); it contributes 27% of the dietary energy supply (Edoka *et al.*, 2009; Kennedy *et al.*, 2003; Kubo & Purevdorj, 1991; Rai, 2003). It has become an indispensable food commodity in the Ghanaian markets and very important to numerous segments of the West African populace (Akowuah *et al.*, 2012; Ekeleme *et al.*, 2008).

In Ghana, the consumption rate of rice is very high for many households. The annual per capita consumption of rice increased from 17.5 kilograms in 1999–2001 to 22.4 kilogram in 2002–2004 (Tomlins *et al.*, 2005) and 24 kilogram in 2010–2011 (MoFA, 2011). The demand for rice is expected to increase at a growing rate of 11.8 percent annually in the medium term (MiDA, 2010). It is also a major economic food commodity serving as food security, a source of calories (Onwueme & Sinha, 1991) and employment to peri – urban and rural lives.

Rice is one of the most significant cereal after maize in Ghana and has become a cash crop for many farmers especially in the Navrongo rice hub (MiDA, 2010; Osei – Asare, 2010). Approximately, 27 percent of rice production in Ghana emanates from the Upper East Region (Ragasa *et al.*, 2013). Rice cultivation in Kassena Nankana West District is mitigating poverty, improving rural development and livelihoods among rice farmers (WARDA, 2005).

Successively, a range of technological interventions have been introduced to assist small-scale farmers to increase yield. For instance, an emergency rice initiative was launched in 2009 with an objective to increase rice productivity in order to improve food security (Abass *et al.*, 2014; Ajah & Ajah, 2010; Buah *et al.*, 2011). Even though, production levels of rough rice between 2000 and 2010 has been growing; they do not meet rice consumption.

According to MOFA (2011), the average yield of rough rice rose from 2.16 mt/ha in 2000 but remains at 2.71 mt/ha in 2010. However, the national food balance sheet (2010/2011) reported that the total national production of rice for consumption was 256,617 mt but was then supported with a total import of 283,000 mt amounting to a total supply of 539,617 mt. Meanwhile 492,000 mt of rough rice was produced in the same 2010.

These low levels of milled rice annually are due to postharvest losses which can be attributed to the untimely manner of harvesting by rice farmers. For instance, at late harvesting, rough rice is susceptible to shattering leading to field losses, then cracks during threshing and milling (Somado & Berhe, 2008). Therefore, timeliness in harvesting is a fundamental influence on field losses, rough rice quality and its marketability. FAO (1989) has also noted that post-harvest losses of rice is attributed to mishandling rough rice and the untimely manner of harvesting rising to about 25%.

Besides, high moisture content at harvest, reduces field losses of rough rice; that is, rough rice is normally harvested at high moisture contents (MCs) of about 20% to 24% wet basis (wb). However, many rice farmers on average harvest below 20% wet basis (Cnossen & Siebenmorgen, 2000). This reduces the output levels of rough rice. Qin and Siebenmorgen (2005) and Siebenmorgen *et al.* (2007) reported that optimal harvest moisture content

(HMC) of rice is key to maximize the output of rice. Therefore, in order to increase production levels, harvesting activities and harvest moisture content must be investigated.

Basically, improvement on postharvest management at farm level during harvesting and handling plays an important role in achieving the potential yield of rough rice. Therefore, there is a vital need to identify the farmers' harvesting and postharvest handling inabilities and the factors influencing the losses (Obeng-Ofori, 2011). This is because, the factors governing farm level losses generally occur before the farm gate in Less Developed Countries (LDCs) (Hodges *et al.*, 2010).

Even though there has been some estimation of losses on harvesting and handling of some rice varieties, these studies were done several years ago. On the other hand, quantitative losses are not adequately documented on rice (var. *Jasmine 85*); which happens to be a very popular variety cultivated in the study area. Therefore, it is imperative to study the quantitative losses of rice (var. *Jasmine 85*). The data that would be obtained from the study on harvesting times and postharvest handling will help assist in identifying possible interventions that could be used to mitigate the current levels of postharvest losses of rice in the area. Thus, this study aimed at estimating the quantitative losses that occur during harvesting, threshing and cleaning of rice (var. *Jasmine 85*) produced at Tono Irrigation Project in the Upper East Region.

The specific objectives of the study were to;

1. Assess farmers' perception on causes, yield gaps and the determinants of harvesting and handling losses of rice (var. *Jasmine 85*)
2. Assess how rice yields at 35 days after heading (DAH) and farmers' date of harvesting influence the level of quantitative losses at shattering, in-field staking and threshing
3. Assess how Harvest Moisture Content (HMC) influence the level of quantitative losses at shattering, in-field staking and threshing

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rice Plant

Rice (*Oryza sativa* L.) is an annual grass that belongs to the family Graminae or poaceae (Agropedia, 2009; FAO, 2013). It has hollow and jointed culms; narrow, sessile leaf blades joined to the leaf sheaths with collars and terminal panicles (Moldenhauer & Slaton, 2001). The rice plant has prominent organs that supports the success of its life cycle. These include the vegetative and the floral parts. The vegetative parts are the roots, culms and leaves; while the floral part is solely made up of the spikelet.

The rice plant usually takes 3 to 6 months from germination to maturity but depends on the variety and the ecology under which the plant is grown (Ranawake *et al.*, 2013). It undergoes a series of developmental process which starts from the emergence of coleoptile to the formation of hard dough on the panicle. Generally, the developmental cycle is categorized as vegetative and productive periods. At the vegetative stage, the plant is totally green and at maturity the straw becomes golden in colour. The vegetative phase includes emergence, seedling development, tillering, internode elongation, culm development. The reproductive phase entails prebooting, booting, heading, grain filling and the maturity stage (Dunand & Saichuk, 2009).

After a complete vegetative stage, the plant bears a terminal shoot called the inflorescence (floral part). It is also known as the panicle. The number of the spikelets on the panicle forms the flower (Moldenhauer & Slaton, 2001). This organ has both the male (anthers containing pollen) and the female (ovary) reproductive organ. At this stage, the rice plant

is noted to have headed. Within the heading period, self-fertilization takes place leading to the development of hard dough. The development of the hard dough also known as the grain results mainly from accumulation of carbohydrates in the pistils of the florets (Dunand, 1998).

2.2 Origin and Taxonomy of Rice

The genus *Oryza*, to which grown rice belongs, have originated at least 130 million years ago and got dispersed as a wild grass (Dogara & Jumare, 2014). There are 24 species of *Oryza* and a chromosome number of $2n=24$ (IRRI, 2005). Among the numerous species of rice, the two cultivated species are diploids: the Asian rice, *Oryza sativa*, which is the widespread rice and the African rice, *Oryza glaberrima*, are the main rice species of research development in rice (Dogara & Jumare, 2014). *Oryza sativa* L. is set categorized into two sub-species based on ecological situations: the *indica* type and the *japonica* type (Linares, 2002). The Asian rice (*O. sativa*) is characterized by good yields and absence of lodging and grain shattering – unlike its African counterpart (*O. glaberrima*) (Jones *et al.*, 1997). Due to these traits, it has called for several research.

2.2.1 Overview of Rice and Research in Ghana

The rice plant *Oryza sativa* L. and its extensive cultivation in Ghana has led to the development of several varietal types. Some categories of varieties are highly susceptible to diseases, pest and environmental stress. These situations called for the strengthening of the existing germplasm to overcome the persisting limitations for some varietal types. Rice research in Ghana is conducted primarily by the Crops Research Institute (CRI) and the Savannah Agricultural Research Institute (SARI) of the Council for Scientific and

Industrial Research (CSIR). Also, the department of Crop Science, University of Ghana, has conducted some varietal research and testing on rice to develop Marshall (*Amankwatia*) variety which was unveiled to Ghanaian farmers in 2010 and has the tendency to tolerate blast disease (Ragasa *et al.*, 2013).

2.2.2 Introduction of Jasmine 85 into Ghanaian rice production

In this half century, aromatic rice has been a preferred rice grain for consumers. Rice breeders in the United States of America delved into the development of an aromatic rice for farmers. A practical approach was to generate a variety from an existing variety with a certain degree of desirable traits. This was IR841 and later named as Jasmine 85 in the United States (Tanasugarn, 1998). Jasmine 85 is an aromatic rice variety developed in 1966, by a Thailand rice breeder: Ben Jackson at the International Rice Research Institute (IRRI). In 1989, the USDA in collaboration with IRRI, University of Arkansas, Louisiana State University, and Texas A & M University, released Jasmine 85 (IR841) to American farmers under the label Jasmine 85 (Oluyemi, 2014; Tanasugarn, 1998).

The variety was then introduced into Ghana in 2009, yielding about 4.5 – 8 tons per hectare and the variety has become the most preferred rice variety to rice farmers (Ragasa *et al.*, 2013). The registration number of Jasmine 85 is ‘CV-107, PI 595927’ (IRRI, 1998), and characterized as aromatic, long grain, good taste and with maturity days within 110 – 120. Aroma in Jasmine 85 is attributed to the presence of 2-acetylcysteine (2AP) (Napasintuwong, 2012; Oluyemi, 2014). The aroma is apparent during its vegetation period as well as cooking periods.

It is noted by several studies that consumers appreciate the aromatic trait of Jasmine 85 over other varieties without the aromatic traits (Abansi *et al.*, 1992; Damardjati and Oka, 1992; Untong *et al.*, 2010). The variety is classified ≥ 7.2 mm of non-polished grain, $\geq 3.2:1$ length-width ratio, $\geq 36\%$ of head rice ($>80\%$ by length) or full grain, and $\leq 14\%$ moisture at storage (Napasintuwong, 2012).

2.3 Importance of Rice

Rice is essential for its nutrition, food security and economics (Wayne & Dilday, 2003). It has a considerable amount of proteins and carbohydrates (Norman & Kebe, 2004). It has 20% of dietary protein and 3% of dietary fat (Kennedy *et al.*, 2003). The cereal crop is mainly consumed in the form of whole grains. It provides more calories than some cereal crops like millet. The utilization of rice in the Asian community accounted for 30% of caloric intake in 2005 (Pandey *et al.*, 2010). Rice farming is the prime activity, energy source and income for about 100 million households in Africa (Sanint *et al.*, 1998). Tran (2004) stated that 1 billion of the world populace are engaged directly or indirectly with rice production. Rice farming serves as a source of employment; which tends to improve food security. Thereby, provides 54% of energy for rural lives and feeds more than 95% of rural families (Norman & Kebe, 2004).

The ability of the staple to absorb over 100 million farmers has actually helped to mitigate poverty among rice growing communities (Sanint *et al.*, 1998). Thus, the livelihoods of people is increasing while income levels also go at a rise. Such livelihoods include transplanting of rice seedlings, harvesting panicles and collection of paddy through threshing. The income made from rice cultivation and post-production activities provides

money to cover the costs of everyday transactions and other societal activities of people in the rural areas.

Its importance has encouraged the research work not only in increasing yield but developing drought resistant varieties that enables farmers to adapt to the erratic rainfall pattern in several ecological zones across the country. An instance being the combinational trait between *O. sativa* and *O. glaberrima* gave Nerica variety. This variety was technologically advanced to stand the low input levels and harsh ecological conditions of African agriculture while boosting productivity.

2.4 Rice Production and Consumption

2.4.1 World Rice Production and Consumption

The global populace is noted to be 7 billion but expected to as much grow to 8.9 billion in 2050, increasing at 47 per cent (United Nations, 2004). This indicates that, the world production of rice is needed to increase. For the reason that, there is the need to meet the expecting rise in demand for rice. In order to meet the demand of the growing global populace, the world's annual rough rice production was needed to increase at 27.6% by the year 2010 (FAO, 1993). Also, it is projected that the world's annual rough rice needs to increase from 520 million tons currently to at least 880 million tons by 2025; which is expected at a growth of almost 70%. This necessity has the tendency to shoot up at one billion tons by the year 2050 (Lampe, 1995). The Asian continent has a huge lead in rice production and consumption of rice but the agricultural lands are almost exhausted (Tran, 1997). This implies that Africa could have a comparative advantage in years to come. The demand of rice is projected to grow in the decades to come but in different amount of

quantity across all regions. The change is mainly attributed to the growth with the human populace. Also, rise in income, expansion of urban communities and consumer preferences has a great influence to the demand of rice. At the global level, per capita rice consumption may become constant, but will increase in Africa, the Middle East, and the Latin Americas while it will decline in some Asian countries that are experiencing diet shifts due to higher incomes and urbanization.

2.4.2 Rice Production and Consumption in West Africa

Rice has become a vital food commodity in the numerous households in West Africa. There has been an extensive endeavor to the strengthening of rice research. There have also been strong developmental programs on breeding and selection in many African countries (Berhe & Mado, 2008), in areas where there are no programs on breeding, such countries benefit from varieties that have been developed to suite the different ecological zones. The region produces about 8 per cent calories of rice and cultivated in two main ecosystems, namely rain fed uplands and lowlands in Sub-Saharan Africa (FAO, 2010b). Rice production in the sub region has risen since the 1970s reaching almost 7 mt of milled rice at the end of the last decade (Defoer, Wopereis, Jones, Lancon, & Erenstein, 2003). The increase at the production base is about 70% extension of the production area and 30% growth in yield (Fagade, 2000; Falusi, 1997). Despite growth in production, the gap between the demand for rice and the sub regional supply is on a growth.

Rice consumption has steadily increased since over the years. Seck (2011) confirmed that the population in the sub region is expected as much to double from 770 million in 2005 to 1.5 billion by 2050. The consumption pattern has overwhelmed production. The average growth of rice consumption is more than 6% per annum and has accrued to over

10 million tonnes of milled rice per annum. The increase in rice consumption cannot be isolated from population growing at a pace of 2.6% per year. Moreover, there has also been an increasing pattern of rice at 1.1% per annum. (Defoer *et al.*, 2003). Therefore, the consumption pattern has been growing between 5% to 6% per annum since 1961 (Nwanze *et al.*, 2006).

2.4.3 Rice Production and Consumption in Ghana

According to Kula and Dormon (2009) Ghana's rice production assessments range from 200,000 to 300,000 mt of paddy of which the bulk comes from the Upper East, Northern and Volta Region. The rice production coming from Upper East is estimated to be 27% (Ragasa *et al.*, 2013; MOFA, 2011). In Ghana, substantial amounts of rice are produced in all regions except central. Sixty percent (66%) of the national production comes from Northern Ghana as provided in Table 2.1.

Table 2. 1 Regional Rice Production, Area Cropped and Yields in Ghana 2009-2010

Region/year	2009			2010		
	Area (Ha)	Production (MT)	Yield (Mt/Ha)	Area (ha)	Production (mt)	Yield (mt/ha)
Ashanti	9,560	12,440	1.23	10,115	27,705	2.74
Brong Ahafo	-	5	-	4,020	6592.8	1.64
Central	4,160	5,090	1.22	4,290	5,241	1.22
Eastern	7,310	19,740	2.70	6,630	20,703	3.12
Greater Northern			4.53	2,323	12,773	5.49
Upper east	39,833	111,273	2.81	62,930	185,877	2.95
Upper west				47,361	135,222	2.86
Volta				4,570	7,291	1.60
Western				21,860	67,229	3.08
				17,130	23,022	1.34
Total	162,000	391,000	2.40	181,228	491,603	2.71

Source: MoFA, SRID, 2010

The yields that are obtained are not encouraging. Average rice yields in Ghana are higher than rice yields in Nigeria, Guinea, and Ivory Coast, but lower than in Mali and Senegal. The yields have been growing at 3 percent annually in Ghana from 2.0 mt/ha in 2004 to 2.5 mt/ha in 2012. Recently, rice yields vary considerably by cropping type but average yields are 2.5 to 4.2 mt/ha in the major season and 2.1 to 3.5 mt/ha during the minor season (Kula & Dormon, 2009).

Rice is widely consumed in Ghana (Chipili *et al.*, 2003); because the Ghanaian population have had a dietary shift to rice (Guisse, 2010). The per capita rice production increased from 17.5 kg to 38 kg within a period of ten years. It is therefore valued to rise up to 63 kg by the year 2018 (MOFA, 2009). At 2010, the per capita consumption of rice was 24 kg per annum (MoFA, 2011). In addition, rice consumption in 2011/12 was 62,000 mt with per capita consumption of rice at 28 kg with urban areas accounting for approximately 76 percent of total rice consumption (CARD, 2010). Due to urbanization, consumption of rice is preferred over most staple foods attributed to the convenience in storage as well as cooking.

2.4.4 Rice Production at Tono

In Ghana, rice production is mostly cultivated on irrigable lands. Among the 22 public irrigation schemes under the government led management (Kranjac-Berisavljevic' *et al.*, 2003), the Tono Irrigation Project is categorized among Kpong, Veve and Afife as large irrigation facility (CARD, 2010). The average paddy yield in all varieties at the Tono Irrigation Project was estimated to be 3.3 mt/ha but 3.2 mt/ha has been estimated for Jasmine 85 (Ragasa *et al.*, 2014).

2.4.5 Assessment of Farmers' Perception on yield gaps and Losses at Farm Level

Assessment of farmers' knowledge on yield gaps and postharvest losses are important. The approach helps to identify the levels of yield gaps and postharvest loss awareness among rice farmers (Abass *et al.*, 2014). This is so because farmers understanding on yield and PHL have received inadequate attention in the studies on losses of rice (Martins, 2013). The fall of yield at farm level is mainly driven by some various constraints such as biological, physiological and socioeconomic. These constraints are addressed by smallholder farmers during the production phase. Such interventions include the use of chemicals in controlling some biotic agents to deter the development of nuisance in the rice fields. Alam and Hossain (2008) indicated that rice yields in different ecosystems is not increasing; despite the introduction of improved package of production practices. Apart from the inadequacies during handling of harvested rice, the yields are also compromised by biotic and abiotic stress. The stress at farm level play a role in field losses.

2.5 General Pre-Harvest and Post-Harvest Operations of Rice

2.5.1 Pre-harvest Operations

Rice farming cannot be separated from farm management. The activities involved in the management of the farm has the tendency to improve the output that is to be achieved at farm level (Lantin, 1999). Therefore, it is always important to adopt appropriate agricultural practices and an improved rice variety that can assure the maximum output at farm level. In addition, the major activities that engage most women especially is the use of pesticides, hand weeding and bird scaring (Norman & Kebe, 2004; Takeshima & Salau,

2010). The activities involved with pre harvest operations is to obtain a farming space, improve the health of soil and the most important part of it all changing the form of soil.

2.5.2 Postharvest Operations

Postharvest operations at farm level is categorized into two main activities. The activities are cutting of matured panicles and separation of edible parts. The two categorized activities is achieved through a physical transformation process (Takeshima & Salau, 2010). The operations at each point contribute to quantitative losses. Depending on the country and the technology available, the activity will vary from farmer to farmer and this explains the wide variations of loss assessment figures globally.

2.5.2.1 Harvesting

Rice is harvested when the crop reaches its maturity. The physiological maturity is often indicated by colour change of the panicle. Also, the ripening stage can be determined within a specified period of maturity. For instance, most of the rice varieties cultivated in the tropics mature within a period of 110 – 120 days. Also, an immature grain is avoided by timely harvest. Therefore, harvesting is appropriately done at 5 days after maturity because to harvest rough rice is dependent on the duration of maturity (Lantin, 1999). The operation is carried out either by cutting the rice stalk or cutting the panicles (Appiah *et al.*, 2011). Harvesting constitute the major constraint to rice production (Somado & Berhe, 2008). It is a vital operation that can increase the quantity of rough rice (Alizadeh & Allameh, 2013) but it can also compromise all efforts to achieve good quality milled rice (Asiedu *et al.*, 2011). In Tono, farmers cut the rice plant from the base and this method is widely practiced in most rice growing countries. It is noted to be cut from about 10 cm - 15 cm above the soil surface (Lantin, 1999). The cut straws are stacked in the field while

harvesting continues. For the duration of the handling stage, activities involved causes physical losses (Naphire, 1997).

2.5.2.1.1 Harvest Moisture Content (HMC) of Rough Rice

Rice moisture content (MC) at harvest is one of the most significant factors influencing the quantity and total economic value of rice (Qin & Siebenmorgen, 2005). Harvest Moisture Content has an impact on the gross income to a producer (Lu *et al.*, 1995). The harvest moisture content also affects the physical losses and the yield of rough rice. Suitable time for harvest is when at least 80% of the panicles have attained full maturity, at a moisture content between 20 - 24% while rough rice has a full ripened colour (Asiedu *et al.*, 2011).

Harvest Moisture Content (HMC) is dependent on the location at which panicles are collected. Therefore, the HMC affects the quantity of rough rice within that location (Bautista & Siebenmorgen, 2005; Khan & Salim, 2005). Moisture level in soil compensate the excess transpiration of water molecules from the surfaces of the kernels. This prevents kernels shattering while attached to the ears of the panicles. In cases where there is high evapotranspiration, paddy is susceptible to excessive shattering especially in rain fed areas.

2.5.2.1.2 Yield of Rough Rice during Harvesting Times

Generally, rice cultivation in Africa is noted to be low – yielding (Jenny *et al.*, 2008). Since then, it has called for the designing of strategies for improvement in the yield of rough rice (Cuevasperes *et al.*, 1995). Many farmers have adopted the used of improved cultivars but have not optimized the appropriate crop management systems. This has then affected the potential yield of rough rice at the farm level (Feil, 1992; Nanfumba *et al.*,

2013). In addition, Good Agronomic Practices (GAPs) in rice cultivation have been adopted especially pest control measures and fertilizer application; whereas the approaches were to augment the yields of rough rice in most developing countries (USDA-National Agricultural Statistics Service, 2008). However, these interventions and the improvements have not really improved the production of rough rice (Tabien *et al.*, 2008).

Additionally, improvements that are needed to increase rough rice during harvesting is met halfway. Therefore, there must be possibilities to increase Head Rice Yield (HRY) through proper crop management practices especially at the farm level. It is also true that farmers encounter several on farm challenges in rice production leading to PHLs. Eliminating the constraints to rough rice yield does not guarantee an increase in production (Ofori *et al.*, 2010). But, the situation must be supported with some level of commitment in terms of adopting improved time of harvesting rough rice at farm level. Tanaka (1976) indicated that there is always a need on the farmer's behalf to know the optimal growth duration for the maximum yield of the variety under cultivation.

2.5.2.2 Threshing and Cleaning

This activity involves the separation of rough rice from the panicle and is mostly obtained by hitting the straws with sticks. Paddy is threshed when the straws receive beating impacts from a stick. With this operation, there is always a high tendency where paddy is lost through incomplete detach of rough rice from the ears of the panicles and the worst is the scattering of paddy due to the impact force from beating stick (Candia *et al.*, 2012).

2.6 Postharvest Loss Assessment

Postharvest Loss Assessment is an important part of any loss reduction and intervention programme (Boxall, 1986). The assessment procedure has the tendency to identify the loopholes for drastic attention. There have been several investigations that have sought into assessing postharvest losses in the Sub – Saharan Africa. IRRI (1997) reported an alarming large estimated loss of 37%. Also, postharvest paddy losses of 35% have been attributed to small-scale farmers, varying varieties and environmental location (Hodges *et al.*, 2010; Somado & Berhe, 2008).

The largest Postharvest Losses (PHLs) usually occur at the farm level (World Bank *et al.*, 2011). This is highly attributed to physical grain loss due to shattering, scattering or spillage during transportation of rough rice from the field. In assessing postharvest losses, results are very much location specific, technology and social behavior practice dependent, and based on sample statistics. The effectiveness of loss assessment studies make stakeholders aware of the need to allocate resources to post-production research, and to also to underline priority areas for research (De Padua, 1999). Physical losses during harvesting of matured paddy at field is based on the estimation of rough rice lost per the measured quadrat as percentage of actual yield (Boxall, 1986).

There has been much emphasis on agricultural production rather than postharvest research in most rice growing communities. Postharvest research has also been classified as a third dimension in the production of rough rice (Kader & Rolle, 2004). But, there has been a growing interest in the important role of postharvest system in the rice value chain. Yet, there has been low research in West Africa, contributing low transfer of postharvest

technology among small scale rice farmers. Researching into the existing postharvest system through loss assessment studies help to identify obstacles.

2.6.1 Harvesting Losses

Harvesting refers to cutting of straws, in – field staking and bundling to the threshing floor (Guisse, 2010). These various activities account for the losses that do occur at farm level (Naphire, 1997). Losses to harvesting vary with the method used to collect rough rice. Harvesting loss of African rice in Madagascar is estimated to be 6.9%. Asian countries encountered an estimated harvesting loss of 4% (Calverley, 1996) where rice farmers in Bangladesh encountered a loss of 1.95% (Huq & Greeley, 1980).

Field stacking is a main way of handling harvested straws. The practice has the tendency of incurring losses ranging from 0.11 to 0.76% (Khan & Salim, 2005). The longer the intermediary piling on the field, particularly where the grain moisture content is high or have collected moisture from the soil, the degree of loss can be attributed to fungal infestation whilst when the moisture level of straw is low, there is a high tendency of shattering losses.

2.6.2 Threshing Losses

Losses to threshing is dependent on the type of method used (Guisse, 2010). The method also varies from country to country. The methods are categorized as manual, animal threading or mechanical. Losses to threshing is due to incomplete removal of rough rice and scattering of rough rice (Candia *et al.*, 2012). In Malaysia, a threshing loss was estimated between 5% - 13% while the Philippines experienced 2% - 6% loss (FAO, 2007).

2.7 Importance of postharvest loss (PHL) reduction of rice

Postharvest losses of rough rice come to play either by physical or qualitative. The losses happen between harvest and consumption (Abebe & Bekele, 2006). In Ghana, postharvest losses of rice is well-known but reduction in the losses of rice is usually considered as a third aspect as compared to rice production and population growth (Kader & Rolle, 2004). But, the reduction of losses on rice is essential. Also, the increasing population in the world is a threat to food security. The extent of postharvest losses does not only consist of physical deterioration of quality grains, but also takes into account sunk cost (total cost of inputs used in producing lost grain).

Secondly, in situations where losses are not addressed in Ghana, it will increase economic pressure and bring about surges in the price of rice. This shows that postharvest system is important. Due to the increase demand for rice on the global market, the economic environment has predicted rice prices that are capable of increasing at 10% - 20% (Pandey *et al.*, 2010). In general, food losses contribute to high food prices, puts pressure on farmers to produce more to compensate the lost grain whiles it put much stress on the ecology (FAO, 2010a).

The reduction of the losses in rice fields shall complement the effort to enhance food security. This approach will improve farm level productivity. Through this, rice farmers will benefit significantly among the rural lives. Therefore, when efforts are geared towards achieving postharvest rice loss reduction, importation of rice in Ghana will not prevail. Also, reduction in losses generate much income for rice actors, improve product quality and safety on the aspect of consumers. Therefore, the combination of cost effective and sustainable strategies has the capacity to promote food and nutritional security among

human lives. PHL reduction is as critical component of farm level production (World Bank *et al.*, 2011).

2.7.1 Strategies to the Reduction of Losses at Farm Level

A systematic scrutiny of rice during production, harvesting and handling is important and a first step in identifying an appropriate strategy for reducing losses (Bell *et al.*, 1999; Kitinoja & Gorny, 1999). Also, the reduction of postharvest loss is not new. Therefore, there is a need to engage farmers in a Commodity System Assessment (CSA) to have the conscious of losses that can occur at each point of postharvest operation.

Primarily, losses start during the pre-harvest period but much concern has centered on production but there has been less yields from the fields. This is recognized to the continuous adoption of planting saved seeds over a period of growing seasons. Contrary, the adoption and use of quality rice seeds has the capacity to decrease the losses. For instance, the adoption of bad seeds that encourage shattering or lodging at field. Therefore, the increase in the supply of quality rice seeds are the appropriate strategy to ensure food security at the production level (Hoque & Haque, 2014).

Furthermore, physical losses of rough rice within post-production system is generally low. Studies have identified series of estimates that have described the extent of the losses. Such estimates have underlined harvesting and handling losses. The losses associated to harvesting can be mitigated when farmers harvest timely. However, farmers do not harvest at the appropriate time. In addition, losses during threshing and drying is well mitigated using appropriate tarpaulin. It is well-known among small scale rice farmers for the use of improvised tarpaulins made out of used sacks. In cases where these prevailing situations are addressed, the losses will be mitigated.

2.8 Factors Influencing Harvesting and Handling Losses

2.8.1 Socio-economic Characteristics of Rice Farmers

There is much demand for rice. It is noted that, farmers in rice production encounter various challenges that needs to be tackled. Such challenges faced at farm level are influenced by the socioeconomic characteristics of rice farmers. These characteristics have not been given much interest in rice losses. In most cases, studies have tackled the issues of productivity (Donkoh & Awuni, 2011). Moreover, when socioeconomic characteristics are studied, it enables planners and policy makers to develop a more friendly – user programs and strategies to the benefit of postharvest losses at farm level.

It is much well-known that farmers in rice farming are of small to medium scale (Amaza & Maurice, 2005; Okoruwa & Ogundele, 2006). The average farm size ranges from 0.6 ha to 1.68 ha while 0.1 to 0.3 considered as small scale farms (Onoja & Herbert, 2012). Yet still, farmers are not able to harvest much rice from the field. This is highly attributed to less schooling among the rice farmers. Mbah (2006) discovered that, 69% of rice farmers are either illiterates or semi illiterates. This indicates that education in agriculture is paramount among rice farmers. Also, education influences the rice output at farm level. Therefore, studies conducted by Horna *et al.* (2005) identified some farmer characteristics that could affect the output of rice production. In the study, some of the identified characteristics were gender and access to farm education.

Subsequently, there are several factors that influences losses at farm level. Some of the variables include acreage, size of tarpaulin to handle rough rice at field, the social behavior of the women while threshing, labour adequacy and competence of the farmer. These socioeconomic variables influence physical losses at farmer fields.

2.8.2 Acreage

Approximately 69% of Ghana's land is for agriculture (USAID, 2011). It is noted that production of rough rice undergo some degree of losses which affect the sustainable and rural development of farmers (Donkor & Owusu, 2014; IFAD, 2008). In most cases, land size in agriculture is either classified as small or average. Approximately 90% of agricultural acreages are less than 2 hectares (MoFA, 2011). Sarah *et al.*, (2014) highlighted in a survey that farm size has decreased overtime. Irrespective of the farm size, usually, the land is capable of producing higher outputs. This require high amount of labour to harvest rough rice at farm level. This result in high level of poor handling of rough rice.

2.8.3 Gender

Gender involvement in rice production and postharvest handling is well recognized among smallholder farmers. In many cases, women are more active in the operations (Akande *et al.*, 2007; Huvio, 1998; WARDA *et al.*, 2008) but their roles in the economic growth continues to be inadequately acknowledged (Mohammed & Abdulquadri, 2011).

In Upper East Region and some rice growing communities, men, women and the youth are major players in rice production and handling of rough rice but most postharvest handling of rice are handled by women. Besides there is division of labour which exists among gender. Meanwhile, the gender pattern for rice cultivation is complex in many places. Therefore, research into gender is an approach to sustainability and for an effective rice development in West Africa. (Agboh-Noameshie *et al.*, 2013). Also, gender has become a cross cutting issue in terms of promoting equity. The issues highlight liaising

male and female farmers to appropriate programs which targets the improvement in household food security and poverty reduction (Ayoola *et al.*, 2011).

2.8.4 Farm Education

Education in rice farming is key; governments around the globe have routinely advocated investment in education (Asadullah & Rahman, 2005). Also, information is consistently an essential pillar in the development of farmers in Upper East Region because their livelihoods can be improved (Meyer, 2005). Information and education raise a positive return to agriculture (Bachhv, 2012; Oladele, 2006). Therefore, farmer's accessibility to information has the tendency to influence the behaviour towards handling of agricultural produce (Asiabaka and Kenyon 2002). In addition, adoption of better access to rough rice handling is dependent on the extent of farm education a farmer engages with. Ganpat and Sespersad (1996) highlighted, the constant interaction with information source will have an effect on the adoption behaviour of the farmer. It is recommended that paddy is harvested as soon as they are physiologically matured and this knowledge can be passed on to farmers through farm trainings.

Hodges & Stathers (2012) stated that it is essential to be able to make out when crops have matured in the field. This technical know-how can be acquired during interactions on farm training activities. The trainings will help farmers to harvest at an appropriate moisture content of around 20-25% (Hodges & Stathers, 2012). The technology transfer to farmers will help to inform, correct decision making and increase the quantity of rough rice collected (Adejo *et al.*, 2012; Aina *et al.*, 1995; Dulle & Ngalapa, 2014; Idiegbeyan-Ose Jerome & Theresa, 2009). The trainings pertaining to postharvest handling will encourage farmers to analyse the prevailing difficulties that they might encounter in the

course of post-production; therefore the challenges which include time of harvest and post-harvest techniques would be tackled (FAO, 2009). Education arises when a farmer with limited knowledge acquires or adopts a newly introduced practice particularly from a fellow farmer within the catchment area of the same crop production (Appleton & Balihuta, 1996; Knight, Wier, & Woldhanna, 2003) Therefore, since such farmers become the point of reference for many farmers; farmers enhance their own postharvest handling management. Also, farm education will give the rice actor a firsthand approach to adjust from poor handling of rough rice to a more improved way of handling the food commodity during and after harvest. In addition, rice farmers need applicable information and knowledge on postharvest handling techniques and opportunities to increase output and to sell their surplus (Agboh-Noameshie *et al.*, 2013).

2.8.5 Labour

The majority of rice consumed in most rice growing communities and some part of the country emanates from rural farmers. They indulge in indigenous practices where family labour and/or hired labour is used for most of the farm operations (Edoka *et al.*, 2014). In addition, agriculture accounts for 70% of labour force (World Bank, 2007). Women for instance, play a vital role contributing 60% – 80% of agricultural labour force (Mgbada, 2000).

Rice is normally cut by hand using different type of labour of which the balance is dependent on farmer acreage (Denning *et al.*, 2013). Around 10 – 15 person-days per acre is required for manual cutting, while 5–7 person-days are needed for manual threshing; losses in manual systems can reach 7–20% depending on the season and local practices (Bautista *et al.*, 2007). The goal of good harvesting is to ensure maximum grain yield by

minimizing grain loss and preventing quality deterioration. In subsistence and small-scale farming systems, these operations are still often carried out manually (Pandey *et al.*, 2010). Smallholder farmers do not only contribute to rice productivity but also to overall economic growth and provision of labour (Biggs & Biggs, 2001).

2.8.6 Usage of Tarpaulins and Threshability of Rough Rice

The use of drying materials is very important in the rice value chain. Such materials are noted to be a tarpaulin. It is more important to use during the time of threshing, especially when there is an absence of a threshing and drying floor. The material is impermeable and mostly used to cover stored produce in dump areas (World Bank *et al.*, 2011). In the absence of tarpaulin, farmers put together opened sacks to serve as an improvised tarpaulin. Even though, farmers make themselves improvised tarpaulins, the size is not proportional to the land size. This improvised material cannot serve efficiently as a tarpaulin would. Moreover, it is permeable and cannot be used in damp areas.

The threshability of kernels to detach from the straw is paramount. At times where rough rice is not detached from the straw, it adds up to physical loss at farm level. It is well observed in rice growing communities that females in rice growing areas have proved to possess particular skills in executing some particular tasks (Agboh-Noameshie *et al.*, 2013); but losses at farm level can be attributed to the social behaviour of women during labour. Therefore, the behaviour of the one threshing determines how much rough rice will be collected.

2.9 Challenges Affecting Rice Farmers at Farm Level

During the production phase of rice, preharvest factors influence the potential yield that could have been harvested. These challenges can result from the incidence of biological

agents, physical stress from the ecology and socioeconomic problems (Thanh & Singh, 2006). It is well noted that the presence of socioeconomic problems contributes to the extent of losses at field. Adepoju (2014) identified pest/diseases and limited access to credit as the most pressing constraint to farmers apart from inadequate storage facilities. Seid *et al.* (2013) and Basappa *et al.* (2007) identified diseases and less capital as challenges faced by farmers. Also, Aidoo *et al.* (2014) also identified that farmers consider limited access to finance/credit as one major constraint at farm level.

Constraints are capable of varying from one place to the other. For instance, different ecologies have different situations depending on the mitigation strategies that are used to address the problem at hand.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was conducted at the Kassena Nankana West District. The district falls within the Guinea Savannah woodlands of Ghana and generally a lowland with a rise and fall landscape. The drainage system of the district is constituted mainly around the tributaries of the Sissili River. It is one of its tributaries, the Asibelika River, which has been dammed to provide the Tono Irrigation facility. The facility is the second irrigable land managed by Irrigation Company of Upper Region (ICOUR). The scheme lies within latitude 10° 45' N and longitude 1° W. It has a total area of about 3840 ha with an irrigable area 2490 ha. The source of water is from river Tono. The irrigation scheme is a storage based gravity-fed irrigation system of which stored water from the dam is diverted to the fields by gravity through large canal and lateral systems to various rice fields. The study was conducted during the major season of 2014.

3.1.1 Study Framework

The study was conducted in three segments: a survey, a technology – verification experiment on farmer fields and a laboratory experiment. The survey sought for farmers' perception on causes of rice loss during harvesting, handling and the capable factors that influence quantitative losses of rough rice at farm level. The technology – verification experiment was carried out to assess the potential losses that do exist during shattering, in – field staking, threshing and cleaning. The activities done at the laboratory sought to measure the harvest moisture content of rough rice at the experimental fields.

The rice variety (*Jasmine 85*) frequently cropped by farmers on the scheme was used for the study. On the selected fields, 2.25 m² quadrats were randomly set to determine shattering losses whereas 25 m² quadrats were also randomly set on farmer fields to determine the losses during in – field staking and threshing. The quadrats were replicated thrice per the variety under study.

3.1.2 Sampling Technique and Sampling Size

A multi – stage sampling approach was adopted and used to select rice farmers. Upper East Region was first and purposively selected because the region has over decades produced rough rice in Ghana. The Tono Irrigation Project is situated in the suburb of Navrongo and the intensive rice cultivation in the region is in the environs of Kassena Nankana West District. It was then purposively selected in the secondary stage of sampling. Six (6) communities were randomly sampled for the survey and 3 communities used for the technology – verification experiment. The selection phase served as the third stage of sampling. To conclude the sampling stage, a conventional statistical model,

$$n = \frac{N}{1+N(\alpha)^2} \quad (1)$$

Where; n=sample size; N=sample frame; and α = margin of error, was used to derive the sample size for the study. With reference to the number of households stated by Namara *et al.* (2011), the project manages about 3,250 rice farmers across three districts: Builsa South, Kassena Nanakana West and Kassena Nankan East, a sample size of 97 was obtained using a margin error of 10%. At most 16 respondents were expected from each of the randomly sampled communities for the survey. However, a sample size of 84 rice

farmers were willing to be interviewed from 6 different communities while 4 rice farmer fields were sampled for the field experimentation using convenient sampling technique.

3.2 Survey

The perception of rice farmers at the catchment area of Navrongo and its environs on quantitative losses of rice were pursued through a survey using a semi – structured questionnaire (Appendix I). The survey was designed to seek farmers’ perception on harvesting and handling losses; stages at which losses are incurred; general characteristics of respondents, economic characteristics; estimation of the losses and factors influencing the losses. The questionnaire was first pretested among farmers at Kapania before administered to the 6 sampled communities.

3.2.1 Determination of Factors Influencing Losses at Field

An ordinary least square regression model was used to examine the explanatory variables that were capable of influencing the harvesting and handling losses of rough rice. The model was adopted from Hutcheson (2011) which is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + e \quad (2)$$

Therefore, the model tested in this study was:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 X_6 + e \quad (3)$$

Where;

Y = Harvesting and Handling losses of rice (metric tonnes/ ha)

X₁ = acreage (ha)

X_2 = gender dummy takes '1' male and '0' female

X_3 = farm education '1' partake and '0' otherwise

X_4 = size of tarpaulin '1' small '2' medium '3' large

X_5 = threshability '1' numerous threshing '0' done once

X_6 = labour (man-days), $e = 0.05$

$\partial Y/\partial X_1, \partial Y/\partial X_2, \partial Y/\partial X_5 > 0$; while $\partial Y/\partial X_3, \partial Y/\partial X_4, \partial Y/\partial X_6 < 0$.

This indicates that acreage, gender and threshability are expected to be positively significant while farm education, size of tarpaulin and labour are expected to be negatively significant.

3.2.2 Ranking Challenges faced at farm level

Kendall's Coefficient of Concordance was used to measure the degree of agreement among the rankings of constraints by respondents using the rank scores of 1 to 6. The challenges were ranked from the most pressing to least pressing as postulated by Legendre (2010). The degree of agreement was estimated from the formula:

$$W_C = \frac{\frac{\sum T^2 - (\sum T)^2/n}{n}}{m^2(n^2-1)} \quad (4)$$

Where W_C = Kendall's Coefficient of Concordance

T = sum of ranks for each perception being ranked,

m = sample size

n = number of perception ranked

3.3 Determination of Quantitative Loss

Quantitative loss was determined by using the weigh in-weigh out approach data collection form (Appendix II). In every procedure, the weight of known sample was determined for each particular stage. The percentage loss for each procedure was determined using Boxall (1986). It states that all residual rough rice at each stage during the farmer's own operation should be collected from the area under study over the obtained yield of the same area. Therefore, the loss assessment at each procedure was estimated using the formula:

$$\text{Percentage Loss (\%)} = \frac{\text{Residual Rough Rice}}{\text{Attained Yield of Harvested Area}} \times 100 \quad (5)$$

3.3.1 Determination of Yields on Improved Harvesting and Farmer Practice

Six (6) quadrats of 2.25 m² were set randomly in 12 farmer fields. Plate 1 a and b shows demarcation of a quadrat and three (3) demarcated quadrats set randomly at the farmer field.



Plate 1 a Demarcation of a quadrat on farmer field, b. Three demarcated quadrats set randomly at farmer field

These quadrats were labeled as plot A while the remaining quadrats labeled as plot B. Panicles were harvested from plot A at 35 Days After Heading (DAH) while panicles of plot B were harvested during farmer's actual harvesting time (42 Days After Heading). The farmer's actual harvesting time could be early or late harvesting. Panicles were harvested by the use of sickle as shown in plate 2. This procedure as developed by AfricaRice Centre in Benin was repeated for the other eleven (11) farmer fields. Yields at different times from the 12 farmer fields were labeled as 35 DAH and Farmer's actual harvesting time respectively.



Plate 2 Panicles harvested from a quadrat

3.3.2 Determination of Shattering Losses during Cutting

In the 12 selected rice farms, a surveyor's tape and wooden pegs were used to demarcate quadrats with sides 1.5 m x 1.5 m. Sickle was used for harvesting because it is the most adopted harvesting tool among the farmers. An experienced farmer was used to harvest the panicles in the quadrats. Residual rice grains on the harvested area that dropped in the plot were immediately collected, cleaned, and weighed separately into paper bags. The

weights of the residual rough rice represent the shattering losses. The total yield of the quadrats was collected and weighed for each of the selected fields. The shattering loss in the quadrats were determined by expressing weight of shattered rough rice as a percentage of the total yield of all the quadrats. The shattering loss was then given by the mean of shattering losses for all the selected fields.

3.3.3 Determination of In-Field Staking Losses during Handling

A quadrat method of 25 m² was used for the determination of intermediary piling losses for 12 farmer fields. Adopting the method used in the determination of shattering losses, panicles were harvested in each quadrat. The harvested panicles were placed on tarpaulin to trap rough rice that would have dropped into the soil as shown in plate 3.



Plate 3 In-field Staking

The bundled straws in each of the quadrats were collected, threshed, cleaned and the subsequent weights recorded. The dropped rough rice on tarpaulin for each quadrat were collected, cleaned, weighed and recorded. The recorded weights of rough rice that dropped gives the in – field stacking loss as shown in plate 4.



Plate 4 Dropped rough rice on tarpaulin

The threshed kernels and the dropped kernels was the total yield of each quadrat under study. The in – field stacking loss in each quadrat was expressed as weight of dropped kernels on tarpaulin as a percentage of the total yield of the quadrat. The losses on a particular farmer field was then expressed as a mean of in – field staking loss in the three quadrats.

3.3.4 Determination of Losses during Threshing and Cleaning

A quadrat method of 25 m² was used for the determination of threshing and cleaning losses. Plate 5 shows a farmer harvesting a 25 m² on to a tarpaulin for threshing.



Plate 5 Staking panicles for threshing

Harvested rice straws were beaten by sticks as it is mostly practiced by the farmers. Unthreshed and scattered rough rice losses were determined. Panicles were carefully

collected from 6 farmer fields using the traditional method of harvesting. A larger tarpaulin was first laid on the threshing floor to trap scattered kernel due to the impact force by the stick.



Plate 6 Farmers beating panicles with sticks

A farmer improvised tarpaulin was then laid on the larger tarpaulin. Harvested straws were then placed on the farmer improvised tarpaulin for threshing as shown in plate 6. The farmer threshed rough rice were collected, cleaned, weighed and recorded while scattered and re-threshed kernels were also collected, cleaned, weighed and recorded as presented in plate 7.



Plate 7 a Threshed rough rice from 25 m² quadrat; b Collected scattered and Unthreshed rough rice

Straws were sorted and subjected to re – threshing. The kernels obtained from re – threshing were cleaned, weighed and recorded. The farmer threshed rough rice, scattered

and re – threshed rough rice were the total yield of each quadrant under study. Scattered and re – threshed rough rice were obtained as a threshing loss. The percentage loss due to scattering and re – threshed rough rice was obtained by expressing weight of the rough rice loss as a percentage of the total yield of the farmer field. The procedure was repeated for the other 5 farmer fields.

3.4 Determination of Harvest Moisture Content of Rough Rice

A quadrat method of 2.25 m² was used for the determination of farmers' harvest moisture content. In each farmer field, the quadrats were triplicated. Harvested rough rice were hand stripped, cleaned and were taken to the laboratory for moisture content determination. The moisture content of harvested rough rice were taken using the methodology adopted by Anwar (2010).

The sub-samples were collected from (12) farmer fields. Anwar (2010) stipulated that samples must be crushed into powdery form. The powdered rough rice is to be kept in a petri dish and placed in a microwave oven to have a preliminary idea on the efficiency of the microwave. The samples were exposed to microwave radiation for 10 minutes. The result was not favorable but was conducted for the second time. The second set of the powdered rough rice were exposed to the microwave radiations at 7 minutes. The samples were taken out and cooled in a desiccator containing silica gel for the purpose of cooling.

After the cooling period, an electronic digital scale (SP-10016204) with weight capacity 7 kg was used to measure the weight of the samples. Moisture content (w.b.) were calculated using the formula:

$$\% W = \frac{A-B}{A} \times 100 \quad (6)$$

Where %W = Percentage of moisture in sample, A = weight of wet sample and B = weight of dry sample

3.5 Statistical Analysis

Different analytical tools were employed for the various segments of the study. Statistical Package for Social Sciences was used to analyse data obtained from the survey. Descriptive statistics: frequency distribution, percentages, mean and tabular analysis were used to analyze the socioeconomic characteristics of respondents and the constraints faced by farmers. The t-test was used to determine statistical inferences of the parameters measured from the technology – verification fields using GenStat Statistical Software 12th edition.

CHAPTER FOUR

4.0 RESULTS

4.1 Quantitative Loss Assessment Survey

The result of this survey unveiled farmer's perception on rice harvesting and handling losses at Tono at the Kassena Nankana West District of Ghana. The survey will serve as the bases for executing good policies to improve existing postharvest handling practices in Ghana.

4.1.1 Socio-demographic Characteristics of Rice Farmers

Eighty-four (84) respondents were interviewed. Thirty-two 32 (38.1%) females and 52 (61.9%) males contributed to the study. A distribution of 51.2% (43) were not actively into farm education (postharvest handling (PHH) and farm trainings). Yet, 48.8% (41) were reported to have involved themselves in farm education.

Table 4. 1 Socio-demographic Characteristics of Respondents (n=84)

Variable	Attributes	Frequency	Percentage
Gender	Male	32	38.1
	Female	52	61.9
Farm Education	Otherwise	43	51.2
	Partake	41	48.8
Acreage	0.2	2	2.4
	0.4	26	31
	0.6	19	22.6
	0.8	20	23.8
	1.0	9	10.7
	<1.60	8	9.5

Source: Field Data generated from Tono Irrigation Project, 2014 Major Season

4.1.2 Levels, causes and stages of Losses perceived by Farmers at Farm Level

Figure 1 shows that a proportion of 10.7% (9) of the respondents perceived to have lost rough rice below (10%). Also, 22.6% (19) of the respondents' level of losses ranged between (10% - 19%) while 25.0% (21) of the respondents perceived to have lost paddy within a postharvest loss of (20% - 29%). But majority of the respondents with a ratio of 41.7% (35) affirmed most of the losses were higher than (30%).

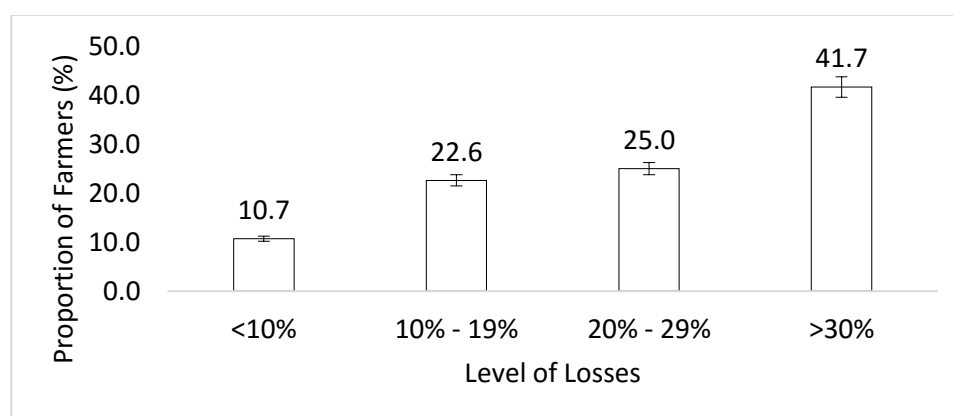


Figure 1 Levels of Postharvest Losses perceived by Farmers

Figure 2 presents the causes of postharvest losses that farmers encountered at farm level. Forty-four 44 (52.4%) of the respondents affirmed that the level of losses was due to time of harvest. But, 13 (15.5%), 15 (17.8%) and 12 (14.3%) of the respondents associated the level of losses to lack of improved seeds, inappropriate planting methods and labour, respectively.

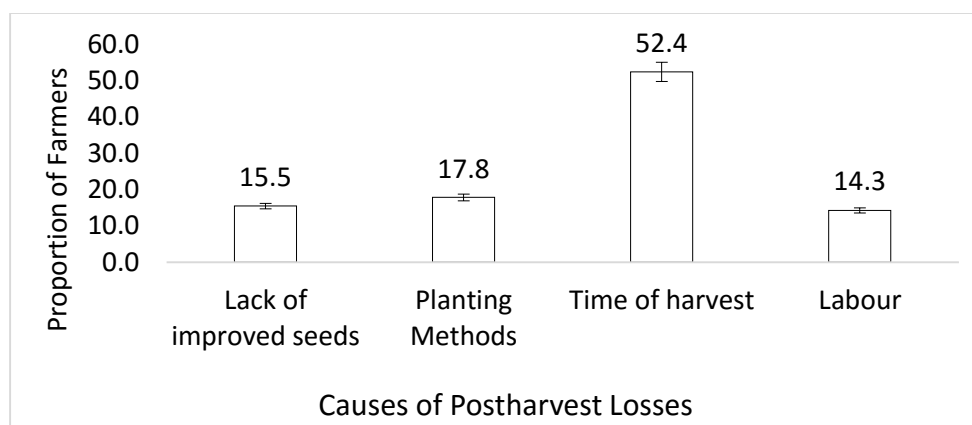


Figure 2 Perception of causes of Postharvest Losses during rice cultivation by farmers at Tono Irrigation Project

Figure 3 shows that threshing represented the stage where the highest amount of rough rice was lost. Harvesting stage was also identified by 21 (25%) of the respondents. Respondents that attributed losses to transportation of harvested rough rice were higher (12, 14.3%) as compared to farmers that made reference to incomplete cutting of panicle (8, 9.5%).

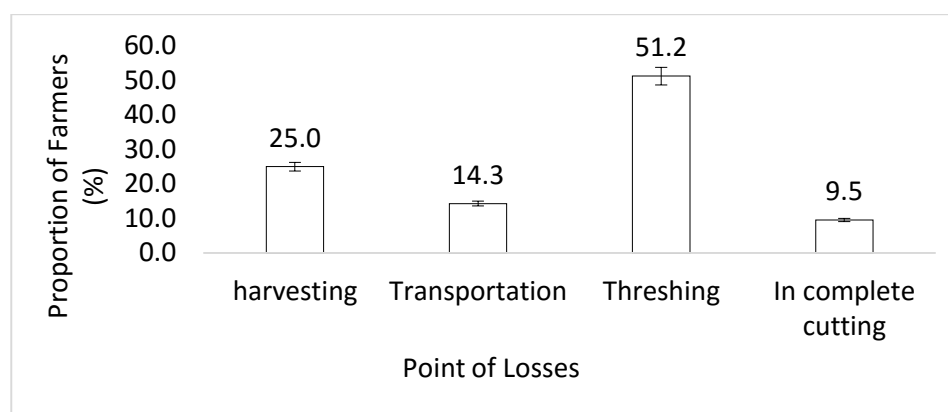


Figure 3 Farmers' perception about Stages where Losses occur at Farm Level

4.1.3 Rice Output, Yield gap, Revenue and Postharvest Losses at 6 Communities

Table 4.2 shows that on an average, 0.68 ha field was under rice cultivation. The total output of rice obtained was averaged at 1855.24 kg (2.7283 mt/ha). Farmers saved an

average rough rice of 481.90 kg (0.708 mt/ha) while a quantity of output lost was 443.81 kg (0.652 mt/ha). Therefore, the output saved for household was not significantly different ($P>0.05$) from the output that was lost to the soil.

Table 4. 2 Rough Rice Output and Postharvest losses

Variable	2014 Major Season
Farm Size (ha)	0.6833
Quantity Produced (mt/ha)	2.7283
Quantity saved (mt/ha)	0.7087 (25.9%)
Quantity Lost (mt/ha)	0.6527 (23.92%)
Quantity Sold (mt/ha)	2.0336
Unit Price (GHS; US\$/0.16 mt)	200; 57.14
Actual Revenue Obtained (GHS; US\$)	2,542; 726.29
Value of Loss (GHS; US\$)	815.88; 233.11
Potential Revenue (GHS; US\$)	3,410.38; 974.29

Source: Obtained from field Data in the 2014 Major Season

Farmers sold a bag of rough rice (160 kg) for GHS 200.00 (US\$ 57.14) and made an actual revenue of GHS 2,542 (US\$ 726.29). The monetary terms of rough rice lost to the soil was valued at GHS 815.88 (US\$ 233.11) as shown in Figure 4.

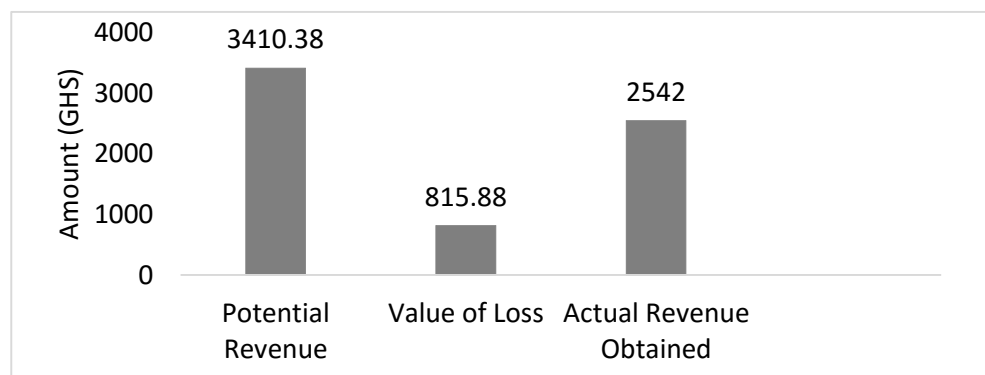


Figure 4 Actual Revenue obtained and potential revenue from a hectare of Rough Rice

Yogbania, Yigwania, Wuru, Biu, Bonia and Korania were communities subjected to be studied for postharvest loss estimation. Table 4.3 shows that Bonia was recorded to have produced the highest total output of rough rice (39.68 mt), than Yigwania, which produced

the least output (15.68 mt). Production of rough rice estimated during the study was 155.84 mt while 37.28 mt was estimated as the total losses of rough rice lost at farm level. Therefore, the total postharvest loss during the survey was estimated at 23.92%. The estimated yield gap at the community level was 0.51 mt/ha with a value of GHS 637.50 (US\$ 182.14) as presented in Table 4.4.

Table 4. 3 Total Production of Rough Rice and Losses at 6 Communities

Community	Total Production of paddy (mt)	Total Losses of paddy (mt)
Yogbania	17.6	4
Yigwania	15.68	4.64
Wuru	22.08	5.28
Biu	28.64	8.16
Bonia	39.68	6.72
Korania	32.16	8.48
Total	155.84	37.28

Source: Field Data Source: generated from Tono Irrigation Project, 2014 Major Season

Table 4. 4 Estimate of Yield Gaps at 6 Communities

Community	Mean Yield at Tono (mt/ha)	Mean Yield at Community Level	Yield Gaps (mt/ha)
Yogbania	3.2	2.75	0.45
Yigwania	3.2	2.42	0.78
Wuru	3.2	2.78	0.42
Biu	3.2	2.65	0.55
Bonia	3.2	2.78	0.42
Korania	3.2	2.79	0.41
Average		2.7	0.51 (18.8%)

Source: Field Data generated from Tono Irrigation Project, 2014 Major Season

4.1.4 Factors Influencing Harvesting and Handling Losses

Table 4.5 presents that acreage, gender, farm education and labour were found to significantly influence the level of harvesting and handling losses at the study area. The regression model was statistically significant at 1%, and the proportion of variance in the

prediction of harvesting and handling losses explained by the individual factors was 0.655. Acreage and gender were found to be positively related with losses in rough rice production. However, farm education and adequate labour were found to reduce harvesting and handling losses. Threshability and tarpaulin size also predicted losses at farm level but did not affect losses statistically.

Table 4. 5 Regression estimate of the factors influencing harvesting and handling losses

Model	Coefficient	Standard Error	t	p>t
Constant	0.234	0.184	1.268	.209
Acreage	0.952	0.155	6.146	.000*
Gender (male=1, female=0)	0.162	0.080	2.040	.045**
Farm Education (partake=1, otherwise=0)	-0.656	0.085	-7.685	.000*
Tarpaulin Size	-0.011	0.059	-.177	.860
Threshability (numerous=1, once=0)	0.076	0.102	.743	.460
Labour	-0.018	0.009	-2.113	.038**

$R^2 = 0.655$; $F = 24.372$; ($\text{Prob}>F = 0.000$); $\text{SER} = 347.782$ (* and ** denote 1% and 5% respectively)

4.1.5 Challenges Farmers face at farm level

The least mean ranked by respondents was the lack of access to tarpaulin. The respondent's highest mean challenge was weather condition. Among the challenges that the farmers ranked as most and least pressing, 84% of the farmers agreed that limited access to tarpaulin was the most pressing challenge during threshing as provided in Table 4.7. The Chi-square of 352.440 shows that the test was significant at 1%.

Table 4. 6 Test of statistics of the challenges faced by farmers at farm level

Number of Respondents	84
Kendall's W^a	.839
Chi-Square	352.440
Df	5
Asymp. Sig.	.000

W^a is Kendall's Coefficient of Concordance

Source: Field Data Tono Irrigation Project, 2014 Major Season

Table 4. 7 Mean ranks of challenges faced at farm level

Challenges	Mean	Rank
Limited access to tarpaulin	1.50	1
Limited access to credit	1.96	2
Labour	2.72	3
Fungal Disease	3.89	4
Bird Scaring	5.21	5
Weather	5.67	6

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2 Yield of Paddy at Different Times of Harvest

Table 4.8 gives a summary of the yields obtained for the two harvesting times. The comparison of yield levels of the two harvest time is presented in Figure 5.

Table 4. 8 Yields at 2 different harvesting times

Harvesting Times	Minimum (mt/ha)	Maximum (mt/ha)	Mean (mt/ha)	Standard Deviation
35 DAH	3.5	6.4	4.8	0.96
Farmer Time of Harvest	2.3	5.4	3.7	1.2

Source: Generated from the experimental fields, DAH (*days after heading*)

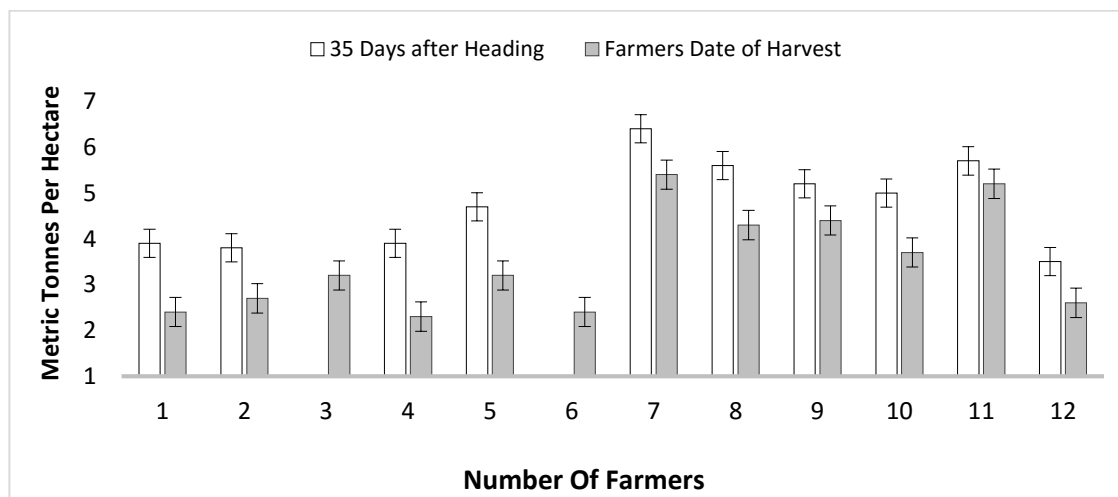


Figure 5 Comparison of yields at harvesting times

4.2.1 Losses at 35 Days after Heading (35DAH)

4.2.1.1 Shattering Losses at 35 Days after Heading (35DAH)

Table 4.9 summarizes the extent of losses that occurred at farmer fields. The losses to shattering has been detailed in Appendix III. The study uncovers that, weight of rough rice that shattered at (3) three different laterals were the same ($P>0.05$).

Table 4. 9 Descriptive statistics of shattered rough rice at 35 days after heading (35DAH)

Parameters	Minimum	Maximum	Mean	Standard Deviation
Threshed Paddy (kg)	0.925	1.895	1.29	0.28
Dropped Paddy (kg)	0.002	0.011	0.006	0.0028
Yield at Quadrant (kg)	0.927	1.906	1.296	0.28
Shattered Loss (%)	0.21	0.88	0.44	0.23

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.1.2 In – Field Stacking at 35 Days after Heading (35DAH)

Table 4.10 shows the effect obtained under the investigation of intermediary piling loss. The piled panicles amassed an average yield of 14.404 kg/25 m² (5.8 mt/ha), of which 0.128 kg/25 m² was estimated as an intermediary piling loss. The overall losses for intermediary piling loss was estimated to range within 0.32 - 1.82% but gave an average piling loss of 0.88%. The experimental fields show that percentage weights at the three (3) laterals were not significantly different ($P>0.05$).

Table 4. 10 Descriptive statistics of in – field Stacking Losses at 35 days after heading (35DAH)

Parameters	Minimum	Maximum	Mean	Standard Deviation
Threshed Paddy (kg)	10.27	21.02	14.23	3.2
Dropped Paddy on Tarpaulin(kg)	0.051	0.319	0.128	0.09
Yield at Quadrant (kg)	10.403	21.281	14.40	3.3
In – field Staking Loss (%)	0.32	1.82	4	0.5
			0.88	

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.1.3 Threshing Losses at 35 Days After Heading (35DAH)

Table 4.11 summarizes the average estimate of threshing loss as 4.4%. Threshing losses were estimated from losses that occurred through scattering of rough rice as a result of beating with sticks and incomplete removal of rough rice from panicles. The incomplete removal of rough rice resulted a loss ranging from 0.05 to 0.83% while the losses due to scattering ranged from 0.054 to 0.683%. The threshing loss was in the range of 1.26 - 9.9% as detailed in Appendix III.

Table 4. 11 Descriptive statistics of threshing Losses at 35 days after heading (35DAH)

Parameters	Minimum	Maximum	Mean	Standard Deviation
Re-threshed and Scattered Paddy (kg)	0.149	1.34	0.62	0.5
Yield at Quadrant (kg)	11.81	16.51	14.10	1.9
In – field Staking (threshing) Loss (%)	1.26	9.9	4.4	3.3

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.1.4 Overall Losses at Farmer Fields at 35 Days after Heading (35DAH)

Table 4. 12 summarizes the losses that occurred at shattering, in – field staking and threshing as obtained at the experimental fields during the 2014 major cropping season. The overall field loss studied at 35 days after heading resulted as 1.79 – 11.34%.

Table 4. 12 Overall Losses studied at 6 Farmer Fields

Point of Losses	Percentage Losses
Shattering	0.21 – 0.88
In – Field Staking	0.32 – 1.82
Threshing	1.26 – 9.9
Total	1.79 – 11.34

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.2 Losses at Farmer Time of Harvest (42 Days After Heading)

4.2.2.1 Shattering Losses (42 Days After Heading)

The output from the quadrat area yielded 0.809 kg. The average shattered rough rice during farmer time (42 days after heading) of harvest ranged from 0.110 kg to 0.250 kg. This gave a shattering percentage loss of 1.96%. Table 4. 13 presents the descriptive statistics on the parameters studied during farmer time of harvest.

Table 4. 13 Descriptive statistics of shattered rough rice at farmer time of harvest

Parameters	Minimum	Maximum	Mean	Standard Deviation
Threshed Paddy (kg)	0.558	0.925	0.794	0.1127
Dropped Paddy (kg)	0.110	0.250	0.016	0.0044
Yield at Quadrant (kg)	0.574	0.939	0.809	0.1127
Shattered Loss (%)	1.18	2.91	1.96	0.6065

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.2.2 In-field Staking Losses (42 Days After Heading)

The quadrat yielded a mean output of 12.464 kg of rough rice with an intermediary loss trapped on tarpaulin was 0.159 kg to 0.453 kg. The in-field staking loss was estimated at 2.53% as presented in Table 4. 14

Table 4. 14 Descriptive statistics of in – field Staking Losses at farmer time of harvest

Parameters	Minimum	Maximum	Mean	Standard Deviation
Threshed Paddy (kg)	9.266	19.018	12.156	2.907
Dropped Paddy on Tarpaulin(kg)	0.159	0.453	0.308	0.082
Yield at Quadrant (kg)	9.503	19.380	12.464	2.941
In – field Staking Loss (%)	1.32	3.59	2.53	0.671

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.2.3 Threshing Losses (42 Days After Heading)

The threshing loss at farmer time (42 days after heading) of harvesting rough rice was estimated at 5.92% with a loss within the range of 0.506 kg to 0.845 kg. Table 4. 15 summarizes the extent of loss during threshing.

Table 4. 15 Descriptive statistics of threshing Losses at farmer time of harvest

Parameters	Minimum	Maximum	Mean	Standard Deviation
Re-threshed and Scattered Paddy (kg)	0.506	0.845	0.652	0.16
Yield at Quadrant (kg)	10.490	12.511	11.336	0.84
Threshing Loss (%)	4.04	7.97	5.92	1.52

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.2.4 Overall Losses at Farmer Fields (42 Days After Heading)

Table 4. 16 shows the losses that occurred at the experimental fields. The losses that occurred at different point of losses during harvesting and handling has been detailed in Appendix III.

Table 4. 16 Overall Losses studied at 6 Farmer Fields

Point of Losses	Percentage Losses
Shattering	1.18 – 2.91
In – Field Staking	1.32 – 3.59
Threshing	4.04 – 7.97
Total	7.80 – 12.75

Source: Field Data Tono Irrigation Project, 2014 Major Season

4.2.3 Summary of Losses at 3 different points

Table 4. 17 shows the comparison of two (2) different harvesting times: 35DAH and the farmer practice (42 days after heading). The overall losses for 35 days after heading and the farmer practice (42 days after heading) were 5.88 ± 3.47 and 10.35 ± 1.94 respectively.

Table 4. 17 Comparison of Losses at 3 different point of losses

Point of Losses	35 Days after Heading	42 days after heading
	% mean loss	% mean loss
Shattering	0.44 ± 0.23	1.96 ± 0.61
In-field Staking	0.88 ± 0.43	2.53 ± 0.67
Threshing	4.4 ± 3.33	5.92 ± 1.52
Overall Losses	5.88 ± 3.47	10.35 ± 1.94

Source: Field Data Tono Irrigation Project, 2014 Major Season (DAH *days after heading*) means ± standard deviations

4.3 Harvest Moisture Content of Rough Rice at Tono Irrigation Project

Table 4. 18 shows the harvest moisture content (HMC) at farm level. The result ranged within 17.1% - 24.7%. The mean moisture content was 20.88 ± 2.56 . Thus, the mean moisture content was not significantly different ($P > 0.05$) from the optimal moisture content (22%) as provided in Appendix III.

Table 4. 18 Experimental Results for Harvested Rough Rice at 12 Farmer Fields

Farmer Fields	Weight of wet powdered sample (g)	Weight of dry powdered samples (g)	Moisture Removed (g)	Moisture Content w.b. (%)
1	9.86	7.77	2.09	21.2
2	9.86	7.43	2.43	24.7
3	9.86	8.12	1.74	17.6
4	10.04	7.68	2.36	23.5
5	9.98	8.12	1.86	18.6
6	10.08	7.79	2.29	22.7
7	9.56	7.75	1.81	18.9
8	9.85	7.80	2.05	20.8
9	10.02	7.73	2.29	22.9
10	9.98	8.27	1.71	17.1
11	10.05	8.03	2.02	20.1
12	10.03	7.93	2.1	20.9

Source: Laboratory Data, 2014 Major Season (w.b. wet basis)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Qualitative Loss Assessment Survey

5.1.1 Socio-demographic Characteristics of Rice Farmers

The gender distribution in this study shows that the males have purposefully made rice farming as a livelihood as acknowledged by Donkor and Owusu (2014). Larger proportion of males are into the production of rice and most of the males worked with their spouses as confirmed by Enwerem and Ohajianya (2012). By observation, majority of the females were more involved in postharvest activities than owning a rice field. The observation made in the study area agreed with the findings documented by Rural Livelihood Development Company (2009). Also, the observation made during the study was also similar to the observation made by Akande *et al.* (2007) and WARDA *et al.* (2008).

The ratio of farmers that did not participate in farm education (51.2%) were higher than the ratio that did participate in farm education programs (48.8%). This suggests that even though the majority of farmers were involved in farm education programs, generally the participatory level was low. From observation, activities of Farmer Based Organizations (FBOs) are well absorbed in the area of study, but it appeared some individual farmers did not fully take the advantage of the organization. The only advantage such category of farmers got from the Community Based Organizations (CBOs) was the access to farm souvenirs and subsidized inputs. The observation made was in agreement with the findings of Mansuri and Rao (2004). Babalola *et al.* (2010) underlined that, a farmer's membership to a community based organization was when the farmer had the interest to access market after harvest of which the findings of this study has affirmed. But the

establishment of community organizations pertaining to farm activities was intended to improve the capacity of its members and not only to access credit and markets.

It was also noted that rice farmers were predominantly small scale farmers. The study buttresses that rice farmers cultivated on smaller farm sizes. The work reveals that 31% of the rice farmers cultivate on a farm size of 0.4 ha while 23.8% of the same respondents cultivate on farm size of 0.8 ha. Therefore, the land size in the study area did not contradict the report by MOFA (2011). That is, the average land size of 0.68 ha implies that agricultural farm lands have decreased overtime as stated by Hazell *et al.* (2010) which reported that due to increasing nonagricultural activities; there has been a reduction of agricultural land size. Also, the result (0.68 ha) is similar to the finding Onoja and Herbert (2012) which stated that an average farm size is at 0.6 ha.

5.1.2 Levels and causes of Losses perceived by Farmers at Farm Level

The level of losses outlined by farmers were guessed estimates but farmers were aware that losses did occur at farm level. Among the respondents, majority (41.7%) perceived that losses did occur at farm level. Among the respondents, majority (41.7%) perceived to loose rough rice above 30%. But, the quantitative loss estimation made during the survey which was approximately 24% was not in agreement with the estimates made by the majority of rice farmers (41.7%) in the study area. The survey shows clearly that there was a significant difference between the losses estimated by the respondents. In addition, this implies that farmers did not know how to measure field losses.

Farmers attributed the level of losses to four (4) major causes. Majority of the farmers (52.4%) considered inappropriate time of harvesting to be the major cause of reducing the output of rice at farm level. Farmers of this proportion suggested that, adoption of Good Agronomic Practices (GAPs) with appropriate inputs such as improved seeds were good

for rice farming. They also established that, time of harvest was the main cause of losses; and showed concern that, appropriate time to harvest was a challenge at farm level. Their concern was not conflicting the findings of Doi *et al.* (2013).

Apart from farmers showing huge concern to inappropriate time of harvesting; a proportion of the farmers (17.8%) associated the losses to unsuitable planting methods. Therefore, the least group of the respondents attributed harvest and handling losses to planting methods, plant density and spacing. This implies that competition in rice field will lessen the optimal yield. Comparatively, a group of the respondents (14.3%) associated losses of rough rice to inadequate labour. The farmers suggested that losses pertaining to labour was also intentional on the side of the workforce. This was characterised by the social behaviour of women during harvesting and threshing. The assertion made by 14.3% of the rice farmers confirmed the observation made by Candia *et al.* (2012). These women exhibit the behaviour of not threshing the straws thoroughly so as to benefit from the unthreshed straws. This also encourages gleaners to garner around, pick the unthreshed straws and the incomplete cut of rice stands in the field for threshing. The threshed paddy by gleaners store the rough rice as a household meal.

5.1.3 Rice Output, Revenue and Postharvest Losses at 6 Communities

The average harvested rough rice during the 2014 major season survey was approximately 2.73 mt/ha. Still, the obtained rough rice during the survey was not different from the yield of rough rice produced in the last 5 years as documented by MOFA (2011). Meanwhile, the Statistical Research Institute Department (SRID) of MOFA estimated an achievable yield of rough rice to about 6 mt/ha. The estimation shows that the study area

was not able to achieve half of the nation's targeted rice output. Moreover, the output obtained from the study area (2.73 mt/ha) was not similar to the average yield of Jasmine 85 (3.2 mt/ha) as Takeshima *et al.* (2013) highlighted in a survey at Tono. The yield gap contributed by biotic and abiotic constraints was estimated at 0.51 mt/ha. In addition, from 2009 to 2011 the average yield of rice output at Tono Irrigation Project was estimated at 3.12 mt/ha as stated by Ragasa *et al.* (2013). But, the surveyed output (2.7 mt/ha) did not conform to the yield (3.12 mt/ha). This suggests that, farmers were not able to access enough amount of inputs such as fertilizers to maintain the yield recorded by Ragasa *et al.* (2013); because there has been a reduction of rice output in the 2014 major cropping season.

Practically, farmers saved some part (26%) of their annual yield for domestic consumption or seeds for the next production season. The result estimated in the study area was not dissimilar from Mishra *et al.* (2012) which reported that farmers save some rough rice for household consumption. This implies that the head of household keeps some rough rice to feed his or her family in the long run. Also, Fu *et al.* (2010) stated that farmers select disease free panicles prior to threshing for the next planting season. However, the decision for farmers to keep disease free rough rice for the next planting season does not guarantee an optimum yield; this is so because the true foundation of the seed might have been lost and has resulted as grain but not a seed.

Farmers lose some amount of rough rice to the soil. It was postulated that the average quantity of rough rice saved for household will not significantly be different from the quantity of rough rice that would be lost during harvesting and handling. This hypothesis confirms that rough rice saved for household consumption (0.7087 mt/ha) was not

significantly different ($P>0.05$) from the rough rice lost to the soil (0.6527 mt/ha). Besides, the amount of rough rice that could have been saved for domestic consumption was equally lost.

An average yield was estimated at 2.73 mt/ha for the 2014 major cropping season. The output lost at field during the same season was valued at GHS 815.88 (US\$ 233.11). This represented a loss of 23.92% of the harvested output at the study area. This per cent loss implies that rice farmers had to receive 76% of the total production. But, farmers received 50% of the total production. The finding correlates with the assertion made by Fu *et al.* (2010) which highlighted that farmers always sell half of harvested rough rice after a cropping season. This study also agrees with the finding studied by Ininda (2008) which also reported that about 50% of farmers produce are sold on the market. Also, 26% of the production went into domestic consumption. Most of the farmers showed intentions of selling some saved bags during the off season. The percentage loss (24%) estimated conformed to the result obtained for West Africa by FAO (2007) which computed a 24% weight loss of rice as field loss. The results of this study is also similar to the findings obtained by World Bank *et al.* (2011) and Hodges (2012). In addition, the estimated loss from the survey was also similar to the documents that were reviewed by Affognon *et al.* (2015) which reported that physical losses of rice was lost at 25.6% without any intervention at farm level.

5.1.4 Factors Influencing Harvesting and Handling Losses

The F – statistic was statistically significant which indicated that the regression model was a good fit. This implies that the explanatory variables in the regression model had a significant and common influence on the extent of losses that did occur during harvesting

and handling at farm level. An approximate 66% of the variation in the quantity of rough rice lost at farm level during harvesting and handling was explained by the specific variables in the model.

Acreage had a highly significant effect ($P < 0.01$) on the level of harvesting and handling losses in the study. Generally, larger agricultural land size has the capacity of giving higher output. Therefore, increase in an acre of land size has the tendency to make farmers face high losses at farm level. This is so because the land size requires a large number of workforce to work on the field. Even when, the farmer has a large number of workforce to engage during harvesting; handling of the panicles will become a problem because the workforce has to cover a larger area and most often in a day. From the model, it was estimated that 0.952 mt of rough rice was capable of going lost at farm level. The findings obtained in this study is in line with the findings of Basavaraja *et al.* (2007) and Enwerem and Ohajianya (2012).

Gender also had a significant effect ($P < 0.05$) on harvesting and handling losses. The harvesting and handling losses were estimated to reach 0.162 mt of rough rice. This study shows that as the number of male farmers' increase in rice farming, male farmers will still encounter some extent of losses at field but their fellow counterparts (females) were expected to experience less losses. This suggests that irrespective of gender, a farmer is capable of encountering losses in rice production. This study disagrees with Babalola *et al.* (2010) which stated that gender and losses had no effect. In addition, to minimize the occurrence of losses, interventions should target the gender perspective and its equality as documented by Rural Livelihood Development Company (2009).

Farm education enhances farmers' knowledge towards harvesting and handling of rough rice. For instance, the variable under examination indicated statistically that, there was also a highly significant effect ($P < 0.01$) on losses with a tendency to reduce harvesting and handling losses of about 0.656 mt. It implies that farm education will demonstrate a significant role in rice farming as it has been affirmed by Wang *et al.* (1996) and Seyoum *et al.* (1998). In addition, Hasnah *et al.* (2004) reported a significant and positive impact of farm education on agricultural activities while Ganpat and Sespersad (1996) stressed that farmers' consistent interaction with information influences the adoption behaviour of farmers.

Therefore, Farmer Field Schools will significantly improve farmers' understanding and build the knowledge of farmers as documented by Asfaw and Admassie (2004), Lunduka *et al.* (2013) and Weir and Knight (2004). Anderson and Feder (2007) established that, when farmers are engaged on farmer field schools, there would be a reflective learning, aiming to improve the capacity of farmers. Instances where this approach is involved among rice farmers, there will be high tendency to reduce the losses that do occur at farm level. Therefore, it is the trainings that has an effect on rough rice output especially when the farmer has the urge to adopt what has been taught.

Also, harvesting and handling losses was statistically significant ($P < 0.05$) to labour. As labour increases by a man – day, there will be a reduction in a loss of rough rice at 0.018 mt. The outcome as estimated in the model agrees with Basavaraja *et al.* (2007) which reported that adequate labour exerted a reduction influence on postharvest losses. This study suggests that, when farmers engage enough labour into contract harvesting

alongside with the household workforce, the losses that do occur during harvest will be minimised.

Tarpaulin size was able to help reduce losses of 0.011 mt/ha but statistically insignificant to the losses that do occur during harvesting and handling. Also, threshability had no effect of reducing losses and was also insignificant to losses at farm gate.

5.1.5 Challenges Farmers face at farm level

The major challenges reported by respondents in the study area included bird scaring, incidence of fungal disease, limited access to finance, accessibility to tarpaulin, labour and weather conditions. Accessibility to tarpaulin was the least mean score (1.50) and the most pressing challenge faced at farm level. It was clear that respondents did not have a problem with the weather condition during production and post-production stages. This led to a situation where respondents ranked it as the least (5.67) pressing challenge during and after production. This was because farmers had access to the irrigation water from the Tono Dam.

The Kendall (W^a) was 0.839. This infers that the degree of agreement among the rankings of the challenges encountered at farm gate was approximately at 84%. This was also evidently shown by the P-value of 0.000. Therefore, there was a significant agreement among the ranking of challenges.

5.2 Yield of Paddy Harvested at Different Times of Harvesting

A survey by Takeshima *et al.* (2013) document reported that the average yield of Jasmine 85 rice was measured at 3.2 mt/ha. From this study, the improved time of harvesting (35 DAH) yielded a mean output of 4.8 ± 0.96 mt/ha. The achieved yield surpassed the yield

that was reported by MOFA (2007). The potential yield can be increased through enhancements in sustainable practices, adoption of underutilized and profitable technologies as stated by Ragasa *et al.* (2013); for example row planting, optimal plant density and spacing has not been well adopted by farmers in most rice growing communities. The yield obtained under improved time of harvesting (35 DAH) can be improved upon to its maximum potential yield. Yet still the estimated output was in the range of 4.5 mt/ha to 8 mt/ha as Ragasa *et al.* (2013) reported. In contrast, the farmer practice (42 DAH) gained a mean yield of 3.7 mt/ha which was not different from the average yield of jasmine 85 as stated in the survey conducted by Takeshima *et al.* (2013). From the hypothesis, the analysis confirms that the outputs were significantly different ($P < 0.05$). This implies that harvesting at 35 days after heading is a sustainable method to harvest rough rice at farm level. The study is in line with the document by Lantin (1999) which established that, the date of physiological maturity of rough rice is within 28 to 34 days after heading. Therefore, this period was an optimum harvest time to collect panicles from the field. This study is also not different from the study conducted by Hossain *et al.* (2009), which stated that harvesting aromatic rice at 30 to 35 days after heading is suitable for higher grain quality in respect to head rice yield.

5.2.1 Shattering Losses

The shattering loss (35DAH) was estimated to be within a range of 0.21% - 0.88% while the farmer time of harvest (42 DAH) gave a range of 1.18% – 2.91%. The results show that farmers at the catchment area of the Tono Irrigation facility that cultivated Jasmine 85 variety lines lost 0.44% of their production as shattering losses (35 DAH) to the soil but that of the farmer practice (42 DAH), the shattered rough rice accounted a percentage

loss of 1.96. The loss estimated for shattering (farmer practice) of Jasmine 85 is similar to 1.56% shattering loss as recorded by Candia *et al.* (2012). This implies that the more the rice plant continues to be in the field, the more it has the ability to shatter.

At the time of this study, the average yield of Jasmine 85 at the Tono was 3.2 mt/ha. The improved harvest time (35 DAH) gave a loss of 0.014 mt/ha. In comparison to the farmer practice (42 DAH), the amount of rough rice lost was 0.063 mt/ha.

The result obtained in this study for shattering loss (35DAH) was different from the findings of Candia *et al.* (2012). The study of Candia *et al.* (2012) affirmed that the variety under study had a shattering property but in this assessment, when the rough rice was harvested a bit late, it shattered even more than the 'Kaiso' variety that Candia *et al.* (2012) studied.

The minimum shattered kernels (35DAH) amassed to 0.002 kg/2.25 m² (0.008 mt/ha), whilst the maximum rough rice that shattered was 0.011 kg/2.25 m² (0.05 mt/ha). The losses that were estimated by Calverley (1994) during cutting for some Asian countries were higher than the estimated shattering loss (35DAH). In contrast, the shattered rough rice during the farmer practice showed a minimum loss of 0.110 kg/2.25 m² (0.5 mt/ha) and a maximum loss of 0.250 kg/2.25 m² (1.1 mt/ha). This study suggests that farmers at the study area encountered huge loss at the cutting base.

5.2.2 In – field Losses

After cutting the matured panicles, farmers primarily pile the panicles in small mounts, the effect of the practice resulted to some quantity of physical loss. The intermediary piling losses of rough rice (35DAH) was estimated in the range of 0.32% – 1.82%. An

average rough rice of Jasmine 85 lost due to small mounts of piled panicles in – field was 0.88% (0.028 mt/ha). To compare with the farmer practice, the assessment shows that, the estimated loss for in-field staking was 1.32% - 3.59%. The mean of in-field staking loss was estimated at 2.53% (0.08 mt/ha).

Since, harvesting entails two points; which includes cutting leading to shattering and placing cut panicles in small mounds. These two points were classified as harvesting. Therefore, the harvesting loss (35DAH) that was studied in the catchment area was estimated as 1.32%, in comparison, the harvesting loss during farmer practice (42 DAH) was 4.49%. This indicates that, the harvest loss (35DAH) of Jasmine 85 was estimated as an average of 0.042 mt/ha, but the farmer practice (42 DAH) gave an estimate of 0.143 mt/ha. Therefore, the percentage loss of harvest (35DAH) was not different from the loss of panicle harvesting method as studied by Appiah *et al.* (2011). The loss figure did not surpass 3% but was in the range of 1% and 3% as reported for South East Asia (FAO, 1997). In addition, Hodges *et al.* (2010) indicated that 1% - 5% was estimated as a result of cutting and handling. This study for both practices was in the range of percentage loss during harvesting. Yet, the less percentage loss was more sustainable to practice.

5.2.3 Threshing Losses

The average threshing loss includes losses due to incomplete removal of rough rice from cut panicles and scattered rough rice due to the exerted force by the beating stick. With reference to the average yield of Jasmine 85 at Tono, the result implies that the minimum and maximum threshing losses of improved practice (35 DAH) was estimated at 1.26% (0.040 mt/ha) and 9.9% (0.32 mt/ha) respectively with a mean loss of 4.4% (0.141 mt/ha).

Candia *et al.* (2012) generated a threshing loss of 4.7%, and it was similar to the threshing loss that had been estimated in this study.

In contrast, the threshing loss of farmer practice (42 DAH) was estimated at 4.04% (0.129 mt/ha) to 7.97% (0.255 mt/ha). Therefore, the threshing loss yielded a mean loss of 5.9% (0.19 mt/ha). But, the average threshing loss experienced by Asian farmers was 3.38% (FAO, 2002, 2007); the threshing loss in this study was closely related to the findings obtained among the Asian farmers. FAO (1997), indicated that 2% - 7% of losses was attributed to mishandling of rough rice at farm level. Therefore, threshing loss for both practices complied with the finding. Still, adequate handling during manual threshing was estimated to be within the range of 1% - 5% threshing loss (Hodges *et al.*, 2010). Therefore, the average threshing loss (35DAH) was in the range.

5.2.4 Harvesting and Handling Losses at Farmer Fields

The farmers were assessed for an overall loss. The results from the experimental fields show that losses associated with shattering and in – field staking of rough rice ranged between 0.21% to 0.88% and 0.32% to 1.82% respectively, while the threshing loss ranged from 1.26% to 9.9%. Among all the losses studied for each activity, there were variations in the approaches of workforce used. The estimated total loss during harvesting and handling at experimental fields were observed to range from 1.79% to 11.34% with an average loss of an approximate 6% (0.192 mt/ha). To compare with the farmer practice (42 DAH), the mean loss was estimated at an approximate loss of 10% (0.32 mt/ha). This result shows that farmers harvested panicles at 7 days after the improved harvesting time (42 days after heading). Meanwhile, the maturity stage of rice (*var. Jasmine 85*) was estimated at 110 – 120 days and harvested within 5 days after maturity as stated by Dawe

et al. (2002). The losses (10%) obtained during the farmer time of harvesting was attributed to the additional days the rice plant stood at field. The study suggests that, harvesting at 35 days after heading has a huge impact to reduce the loss that farmers encounter at farm level. Therefore, farmers would be capable to reduce the estimated loss (24%) during the survey to about 6% as reported by FAO (2007) and Hodges *et al.* (2010).

5.3 Harvest Moisture Content of Rough Rice at Tono Irrigation Project

It was postulated that harvest moisture content (HMC) by farmers were significantly different from an optimal moisture content of 22%. The study uncovers an on – field HMC (20.88%) which was not significantly different ($P>0.05$) from the HMC stated by Hodges and Stathers (2012). The result of this study agrees with the findings of Wang *et al.* (2004). Qin and Siebenmorgen (2005) reported that, high significant of field losses were incurred if HMC is less than 22%.

The HMC deviated from 20.88% by 2.56%. This occurrence was dependent on harvest location and harvest date as studied by Lu *et al.* (1992). Siebenmorgen *et al.* (1992) and Wang *et al.* (2004) confirmed that, at a given variety from a particular location, the harvest moisture content generally decreased linearly with the harvest date and increased during cutting based on in – field stacking. It was observed that, panicles were stacked in – field as women continue harvesting. Thus, the hygroscopic nature of rough rice picks up moisture when stacked. Siebenmorgen *et al.* (1992) stressed that, the presence of moisture at field increased the harvest moisture content, particularly during late harvesting and when the harvest moisture content of rough rice was low. The findings from the experimental fields is in line with the study conducted by Jodari and Linscombe (1996), which identified that harvest moisture content had the tendency to rise from one

percentage point with a 5 mm rainfall, and could rise up as much as four percentage points depending on the atmospheric pressure. Therefore, the yields of rough rice was largely dependent on harvest moisture content and location because when the field was with no moisture, the rate at which rough rice will shatter will be high but at periods where moisture level was high, kernels will still be attached to the ears of the panicles.

CHAPTER SIX

6.0 CONCLUSIONS

On the loss assessment survey, it was observed that both male and female farmers were into rice cultivation. Despite the numerous campaign and awareness that had brought the attention of female farmers owning agricultural fields, practically, males were predominant over female farmers.

The survey indicated that, a proportion of farmers engage themselves in Farmer Field Schools (FFS) while others did not. Therefore, there was an equal distribution of farmers that did participate and that did not participate in FFS.

Subsequently, from the perspective of the farmers 52.4% associated the level of losses to inappropriate time of harvesting. Apart from that, farmers perceived different levels of losses. The losses that were perceived by farmers were guess estimates. Therefore, farmers had no formal way of estimating or measuring the losses that were encountered at farm level. In addition, 51.2% emphasised that the most point of losses that was during threshing. As a result, the survey showed that almost all the rice farmers interviewed indicated that losses of rough rice at farm gate is a major challenge.

Small scale farming is predominant in the Ghanaian agriculture. It was not surprising that farmers were farming on an average field of 0.68 ha field. The output from the field (2.7 mt/ha) did not match up with the achievable yield of rice (6 mt/ha) as documented by Statistical Research Institute Department (SRID) of the Ministry of Food and Agriculture. The amount of rough rice lost (0.652 mt/ha) is not different from the rough rice saved (0.708 mt/ha). This shows that, the amount of rough rice saved, either for household

consumption or to be sold later on the market was just equal to the rough rice lost to the soil. Therefore, the economic loss was valued at GHS 815.88 (US\$ 233.11) (23.92%).

There are so many factors affecting physical losses at farmer fields. The factors studied are 6 explanatory variables. Acreage, gender; farm education and labour statistically predicted the losses during harvesting and handling. The effects of the factors influencing harvesting and handling losses were different. Acreage and gender influenced the losses positively whilst adequate labour and training of farmers on harvesting and handling losses significantly predicted a reduction in loss of rough rice at farm level. The adjusted coefficient of determination (approximately 66%) indicated that the quantity of rough rice lost at farm level during harvesting and handling was explained by the explanatory variables in the model.

Farmers' accessibility to the use of tarpaulin during handling of harvested rice straw at farm level was important. It was observed that during threshing where majority of farmers and a large number of work force share one tarpaulin whilst some farmers come along with an improvised tarpaulin made out of used poly sacs.

The yield of rice among rice farmers was not encouraging at field. Farmers harvested when the entire field has turned golden straw. This stage of the rice plant compromises the full potential of rough rice. It was shown in the study that, harvest at 35 days after heading yielded (4.8 mt/ha) more than the time the farmers chose (42 days after heading) to harvest (3.7 mt/ha). Therefore, to harvest at 35 days after heading is more vital and has the tendency of achieving high head rice yield (HRY).

Harvesting losses included shattering and in – field staking. The loss that was estimated during harvesting is 1.32%. This implies that farmers were losing an average rough rice of 0.042 mt/ha. Subsequently, 4.4% of rough rice was lost during threshing. Practically, farmers were losing an average rough rice of 0.141 mt/ha. The overall loss that occurred during harvesting and handling ranged 1.79% to 11.34% with an average loss of 6%. Harvesting at 35 days after heading coupled with good agronomic practice can reduce farm level losses to about 6% or less. This approach can help to stabilise the rate at which rice is lost at farm level.

Finally, studies have noted that farmers do not harvest at an appropriate moisture content. However, from the experimental fields, farmers harvested at $20.88 \pm 2.56\%$ moisture content. This harvest moisture content was highly attributed to the location and the soil moisture content.

6.1 RECOMMENDATIONS

The recommendation are categorised into two (2) parts. It targets the socioeconomic improvement of farmers and the academic discourse. The following recommendations are suggested:

It is well-known that rice is an essential cereal crop. It serves as a source of energy to many lives. Therefore, this study highly endorses important postharvest loss reduction programmes to rice farmers through advocacy and awareness. When a loss reduction campaign is coupled with potent and sustainable food systems, the yield gap will be addressed. A campaign like this should incorporate competitive rice production, appropriate harvesting times and farm field schools among identified Community Based

Organisations (CBOs) and Farmer Based Organisations (FBOs). Through the implementation of a loss reduction programme campaign, there will be high tendency to conserve and convert rice loss to plate. This approach will widen the understanding of PHL among rice farmers. When programmes like Farmer Field Schools (FFS), and exchange visits are implemented within rice growing communities; it will bring on board both extension personnel and farmers. For instance, when rice farmers are taught loss reduction through demonstration fields, the prevailing losses at field will be lessened. Moreover, such programmes will increase awareness among rice farmers, private sector and high policy level. The programme will then build the capacity of farmers to produce more rice. Furthermore, food availability will then expand within the local rice markets. For that reason, rice farmers or local rice sellers can be linked to the Ghana School Feeding Programme (GSFP). This will then support food availability among school children and hence, create more market openings for farmers who fall short of international standards.

Secondly, loss assessment and reduction studies should be conducted at different rice growing communities on the newly released rice variety (CSIR-AGRA rice). The study will serve as a means to inform the breeders whether the variety stands its full potential on the aspect of PHLs. In addition, a research pertaining to the variety will unveil more data to understand postharvest loss situation on the newly released rice variety.

Also, since rough rice is highly processed through parboiling in the environs of Navrongo and some rice growing communities, a loss assessment study could be conducted on parboiled rice to evaluate the quantity and nature of losses that women parboilers

experience during the off – farm activity. The economic losses associated with parboiling of rice at various stages can also be assessed.

In addition, since the study did not delve into the losses that occur during milling, a loss assessment study can be looked at some optimal harvest moisture content (HMC) and the effect on rice milling quality.

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APPENDICES

APPENDIX I: QUESTIONNAIRE ON ESTIMATING QUANTITATIVE LOSSES DURING HARVESTING AND HANDLING OF ROUGH RICE

The quantitative loss assessment survey seeks to estimate losses incurred at farm level and your responses to these questions will be supportive to the study. Information given to the survey will be used for academic and research purposes. The information will be treated confidential. We humbly ask for your cooperation to make this a success.

1. Gender: A. Male B. Female
2. What rice variety do you cultivate?
3. Do you participate in postharvest handling training? 1. Yes [] 2. No []
4. Do you experience postharvest losses at farm? 1. Yes [] 2. No []
5. What percentage quantity of loss do you experience?
 1. <10% 2. 10%-19% 3. 20%-29% 4. >30%
6. Do you know how to measure the losses perceived above? 1. Yes [] 2. No []
7. What are the causes of the losses?
 1. Lack of improved seeds 2. Planting Methods 3. Time of Harvest 4. Labour

1=very high, 2=high, 3=moderate	1	2	3
a. Lack of improved seeds			
b. Planting Methods			
c. Time of Harvest			
d. Labour			

8. At which stage do you experience the highest losses?
 1. Harvesting 2. Transportation 3. Threshing 4. In-complete cutting

FARM AREA UNDER CULTIVATION AND LOSS COMPUTATION

(Av. Yield of Jasmine 85 at Tono Irrigation Project is at (3.3 mt/ha or 3300kg/ha)

Takeshima *et al.* (2013); raw data from CRI/SARI/IFPRI survey (2012 – 2013)

9. Rice field under cultivation (ac.) 1 Ac. = 0.4 Ha	Total Volume of Paddy produced / (number of bags)	Weight per bag	Volume of paddy used for household consumption/ no. of bags	Volume stored (kg)/number of bags at store	Total volume of bags for sales (kg)/Supply
Computed PHL (Y)					

10. How much do you sell a 160 kg sac of rough rice?

11. Do you use tarpaulin? 1. Yes [] 2. No []

12. What is the size of the tarpaulin? 1. Small 2. Medium 3. Large []

13. How do you get access to tarpaulin? 1. Self-owned 2. Hired 3. Improvised

14. How many times do you thresh harvested straws? 1. Once 2. Numerous

15. How many work force do you use to harvest and thresh harvested straws?

16. How many days do the work force use to complete the task?

17. Estimated man days during harvesting and handling.

CHALLENGES FACED AT FARM LEVEL

Rank the challenges in order of most pressing to least pressing using numerical scales from 1 to 5.

Challenges	Rank (using 1 most pressing)
Bird Scaring	
Fungal Diseases	
Limited Access to Credit	
Access to tarpaulin	
Labour	
Weather	

APPENDIX II: DATA COLLECTION SHEET (FIELD WORK)

Data sheet for loss assessment during manual harvesting operation

a. Baseline information (Control)

Date of harvesting----- Farmer No..... Village-----

Variety planted----- Planting date -----

Improved harvesting: (35DAH)

Plot No	Plot size	No of hill	Label on sampling bag	Score of threshability	Field moisture contents (of grains collected outside the plots)				Weight of grains from sampled straws	Mean moisture contents
					Rep 1	2	3	Mean		
A1										
A2										
A3										

a. Farmer's Harvesting Date

Actual Harvesting Time -----

Or Early Harvesting Time -----

Plot No	Plot Size	No of Hill	Label On Sampling Bag	Score of Threshability	Field Moisture Contents				Weight of Grains from Sampled Straws	Mean Moisture Contents
					Rep1			Mean		
B1										
B2										
B3										

Actual harvesting time for collecting shattered grain

Plot No	Plot size	No of hill	Weight		
			Weight of dropped grains	weight of the threshed grain	total weight of grain in the plot
C1					
C2					
C3					

Losses due to grain dropping during intermediary piling (infield staking)

Plot No	Plot size	Weights			Field moisture contents			
		weight of the grain dropped on first tarpaulin before threshing	weight of the threshed grain	total weight of grain in the plot	Rep1	Rep2	Rep3	Mean
Plot 1	5m x 5m							
Plot 2	5m x 5m							
Plot 3	5m x 5m							

Data sheet for loss assessment during Threshing and Cleaning

a. Farmer's Manual Practices

Plot No	Plot size	Sample size	Weight of farmer threshed paddy	Mean moisture content of farmer threshed paddy	Weight of scattered grains	Weight of grains from re-thresh all those straws	Label on sampling bag (1kg) FMTP
D1	5m x 5m	1/3					
D2	5m x 5m	1/3					
D3	5m x 5m	1/3					
use improved harvested panicle samples from plot d only							

APPENDIX III: TABLES**Shattering losses at 35 Days After Heading (35DAH)**

Shattered grains				
Farm No	Average Weight of threshed grain in quadrant (kg)	Average Weight of dropped grains (kg)	Average Total weight of grains in quadrant (kg)	Average shattering in the quadrant (%)
1	1.551	0.005	1.556	0.32
2	1.078	0.007	1.085	0.65
3	1.895	0.004	1.899	0.21
4	1.236	0.011	1.246	0.88
5	1.611	0.01	1.621	0.61
6	0.925	0.002	0.927	0.21
7	1.143	0.004	1.147	0.34
8	1.072	0.008	1.08	0.74
9	1.063	0.004	1.067	0.37
10	1.224	0.003	1.227	0.24
11	1.458	0.006	1.464	0.41
12	1.224	0.003	1.227	0.24

In – field Stacking Losses at 35 Days After Heading (35DAH)

In field stacking				
Farm No.	Average Weight of threshed grain in quadrant (kg of paddy)	Average Weight of dropped grains that dropped first on tarpaulin before threshing	Average Total weight of grains in quadrant (kg of paddy)	Average in field stacking in the quadrant (%)
1	17.237	0.319	17.556	1.82
2	11.999	0.055	12.054	0.46
3	21.018	0.262	21.281	1.23
4	13.729	0.162	13.892	1.17
5	17.896	0.222	18.118	1.23
6	10.266	0.137	10.403	0.32
7	12.704	0.061	12.744	0.48
8	13.864	0.059	13.923	0.42
9	11.808	0.051	11.859	0.43
10	13.064	0.077	13.714	0.56
11	16.225	0.079	16.305	0.48
12	10.948	0.051	10.999	0.46

Threshing losses at 35 Days After Heading (35DAH)

Farm No	Re-threshed collected (kg of paddy)	Scattered grains collected (kg of paddy)	Re - threshed and scattered grains collect	Threshed paddy	Yield of quadrant	Grain loss (%)
1	0.302	0.683	0.985	14.536	16.506	5.97
2	0.314	0.348	0.662	11.499	12.823	5.16
3	0.825	0.511	1.336	10.818	13.49	9.9
4	0.074	0.312	0.386	15.499	16.271	2.37
5	0.05	0.159	0.209	13.186	13.604	1.54
6	0.095	0.054	0.149	11.659	11.808	1.26

Shattering losses (Farmer Practice)

Farmer No.	Average Weight of threshed grain in quadrant (kg)	Average Weight of dropped grains (kg)	Average Total weight of grains in quadrant (kg)	Average shattering in the quadrant (%)
1	0.852	0.02	0.872	2.29
2	0.754	0.011	0.765	1.44
3	0.833	0.025	0.858	2.91
4	0.924	0.011	0.935	1.18
5	0.753	0.011	0.764	1.44
6	0.925	0.014	0.939	1.49
7	0.843	0.02	0.863	2.32
8	0.772	0.015	0.787	1.91
9	0.663	0.018	0.681	2.64
10	0.724	0.013	0.737	1.76
11	0.558	0.016	0.574	2.78
12	0.924	0.013	0.937	1.39

In – field Stacking Losses (Farmer Practice)

Farm No.	Average Weight of threshed grain in quadrant (kg of paddy)	Average Weight of dropped grains that dropped first on tarpaulin before threshing	Average Total weight of grains in quadrant (kg of paddy)	Average in field stacking in the quadrant (%)
1	15.211	0.453	15.664	2.89
2	9.54	0.355	9.895	3.59
3	19.018	0.362	19.38	1.87
4	10.729	0.362	11.091	3.26
5	13.896	0.252	14.148	1.78
6	9.266	0.237	9.503	2.49
7	10.704	0.361	11.065	3.26
8	11.864	0.159	12.023	1.32
9	11.408	0.251	11.659	2.15
10	10.064	0.277	10.341	2.68
11	14.225	0.379	14.604	2.59
12	9.948	0.251	10.199	2.46

Threshing losses (Farmer Practice)

Farm No	Re-threshed collected (kg of paddy)	Scattered grains collected (kg of paddy)	Re - threshed and scattered grains collect	Threshed paddy	Yield of quadrant	Grain loss (%)
1	0.202	0.643	0.845	10.536	12.226	6.91
2	0.214	0.348	0.562	9.499	10.623	5.29
3	0.325	0.511	0.836	8.818	10.49	7.96
4	0.174	0.332	0.506	11.499	12.511	4.04
5	0.155	0.359	0.514	10.186	11.214	4.58
6	0.195	0.454	0.649	9.659	10.957	6.72

Sample	Size	Mean	Variance	deviation	of mean
%35days after heading	10	1.0836	0.04625	0.2151	0.06801
Farmer date of harvest	12	0.8355	0.07324	0.2706	0.07813

Difference of means: 0.248

Standard error of difference: 0.106

95% confidence interval for difference in means: (0.02733, 0.4689)

Test of null hypothesis that mean of 35 Days After Heading is equal to mean of Farmer

Date of Harvest

Test statistic $t = 2.34$ on 20 d.f.

Probability = 0.030

Harvest Moisture Content of Rough Rice at Tono Irrigation Project

Identifier	Minimum	Mean	Maximum	Values	Missing
Moisture	17.10	20.88	24.70	12	0

One-sample t-test

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
Moisture	12	20.88	6.556	2.560	0.7391

95% confidence interval for mean: (19.26, 22.51)

Test of null hypothesis that mean of moisture is equal to 22.00

Test statistic $t = -1.51$ on 11 d.f.

Probability = 0.159

Kendall's W Test

Ranks	
	Mean Rank
Bird Scaring	5.22
Fungal Disease	3.90
Limited Access to credit	1.98
Access to tarpaulin	1.51
Labour	2.73
Weather	5.66

Challenges	N	Mean	Standard Deviation	Minimum	Maximum
Bird Scaring	84	5.21	0.64	3	6
Fungal Disease	84	3.89	0.56	3	5
Limited Access to credit	84	1.96	0.83	1	4
Limited Access to tarpaulin	84	1.50	0.59	1	3
Labour	84	2.72	0.92	1	4
Weather	84	5.67	0.49	4	6

Paired Samples Test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Quantity consumed – Quantity lost	38.095	631.080	68.856	-98.857	175.048	.553	83	.582