Food loss measurements in the rice supply chain of Olam Nigeria

Analysis of the pilot study results

M.G. Kok and H. Snel

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This research project has been carried out by Wageningen University & Research in partnership with The Sustainable Food Laboratory, the Rockefeller Foundation and Olam International.

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Photo cover: Herman Snel

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List of abbreviations and acronyms

CEO	Chief Executive Officer
CLP	Critical Loss Points
FAO	Food and Agriculture Organization
FLW	Food Loss and Waste
FReSH	Food Reform for Sustainability and Health
GAA	Global Agri-business Alliance
GAP	Good Agricultural Practices
GHG	Greenhouse Gases
HLPE	High Level Panel of Experts
IRRI	International Rice Research Institute
SRP	Sustainable Rice Platform
UNDP	United Nations Development Programme
VCDP	Value Chain Development Programme
WBCSD	World Business Council for Sustainable Development
WCDI	Wageningen Centre for Development Innovation, Wageningen University & Research
WUR	Wageningen University & Research

Executive Summary

Of all the food produced for human consumption at a global level, approximately 1/3 is lost or wasted, amounting to over 1.3 billion tons of food per year (FAO, 2011)(HLPE, 2014). Reducing food loss can improve food security, nutrition and the sustainability of food systems (FAO, 2018) (Lipinski, Hanson, & Lomax, 2013)(FAO, 2013)(HLPE, 2014).

Wageningen University & Research (WUR) and the Sustainable Food Lab established a partnership with Olam to run a pilot study to measure and assess the losses that occur throughout a portion of Olam's rice outgrower initiative in Nigeria. The following report documents the process and results of the conducted pilot study where we assessed the magnitude of loss within a sample of 60 rice outgrower farms from 3 states by measuring losses from the moment rice is harvested until the moment rice is received in Olam's procurement warehouse. The pilot study has been conducted within the context of a collaborative action research project, "Business Action on Smallholder Crop Losses in African Food Systems" funded by the Rockefeller Foundation's Yieldwise initiative.

The general objectives of this pilot study were centered around understanding the magnitude and impact of losses occurring in the rice outgrowers initiative to assess:
- How much losses occur in the rice outgrower value chain operated by Olam in Nigeria
- Where the critical loss points are within the different stages in the rice value chain
- What the impact of those losses might be in terms of economics, resource use efficiency and GHGs
- Potential investment areas to reduce losses
- Testing the measurement approach for business value and replication across other Olam's rice origins

Data from this pilot study indicate that on average there is a **total loss of 35% of rice** from the moment that it is harvested up to the moment when rice is graded and sorted and is accepted by Olam's procurement warehouse. Data showed that the percentage of loss varied strongly from farm to farm, with losses ranging from 8% up to 55%.

Two critical loss points within the Rice value chain were identified:
- **12% of losses of actual yield are generated during harvest**
- **11% of losses of actual yield are generated during threshing**

On average 2550 Kg CO^2 are emitted per tonne of rice produced. These GHG emissions result from the way crop residues are being handled on farm and from rice methane production. Based on the calculated loss of 35% of rice from this study, it is estimated that roughly 850 Kg CO^2 per tonne of rice are emitted by rice that is harvested but not ending up being consumed by humans. Crop residue management practices have strong potential to reduce emissions significantly.

Water utilised for the production of the 35% of total yield that was lost is wasted water as the rice produced was never utilized for human consumption.

Outgrowers lose out on approximately 520 USD per hectare due to rice losses and the 35% of the rice that is harvested does not reach the market. Additionally, a proportion of the costs incurred for the purchasing of seed material and fertiliser costs, along with labour costs is wasted.

Effective low-cost technologies and innovative strategies to reduce loss, improve resource use efficiency and reduce GHG emissions within the rice supply chain will require strong collaboration and engagement with stakeholders who aspire to benefit from reduced levels of loss and are committed to systemically transforming the rice sector. Efforts to reduce losses must go hand in hand with systematic monitoring and tracking through the integration of loss measurement methodologies that measure loss at different stages of the value chain. This pilot study concludes that targeted investments to reduce food losses in the rice value chain have the potential to: improve smallholders' and labourers' livelihood; enhance the stability of the supply chain; improve the quality of the product; improve food and nutrition security at a national level; and reduce the environmental footprint of rice production in Nigeria.

1 Introduction

Of all the food produced globally for human consumption approximately 1/3 is lost or wasted, amounting to over 1.3 billion tons of food per year (FAO, 2011)(HLPE, 2014). These losses directly and indirectly have economic, social and environmental implications. Reducing food loss can improve food security and nutrition, and the sustainability of food systems (FAO, 2018).

The Sustainable Development Goal 12 [1](responsible consumption and production patterns) of the United Nations Global Agenda for Sustainable Development[2] engages all actors in the food system to set in motion collective action in order to leverage efforts to reach the global targets for food loss reduction. Within the aforementioned goal, target 12.3 has the ambition to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses by 2030.

Reducing food loss and food waste (FLW) has proven to be an effective mechanism for food and agriculture based companies to reduce their exposure to a variety of financial risks, supply chain risks and regulatory risk. Additionally, targeted investments to reduce on-farm losses at the production level have the potential to improve smallholder producers' income, their livelihood and food security. Additionally, reducing food loss and food waste from farm to fork has the potential to improve local, regional and global food and nutrition security whilst simultaneously reducing the environmental footprint of local and global food systems (Lipinski et al., 2013)(FAO, 2013)(HLPE, 2014). Potential interventions to reduce postharvest losses require relatively modest investment and can result in high returns compared to increasing the crop production to meet the food demand.

Wageningen University and Research (WUR) and the Sustainable Food Lab established a partnership with Olam to run a pilot study to measure and assess the losses that occur throughout a portion of their rice outgrower initiative in Nigeria. Olam has a global commitment to SDG 12.3 to reduce food loss and waste, and is a leader in a number of alliances such as Champions 12.3, Global Agribusiness Alliance, the Sustainable Rice Platform (SRP) and the World Business Council for Sustainable Development (WBCSD).

The following report documents the process and results of the pilot study conducted within Olam's rice outgrower initiative in Nigeria where we assessed the magnitude of loss within a sample of 60 rice outgrower farms from 3 states. The pilot study has been conducted within the context of a collaborative action research project, "Business Action on Smallholder Crop Losses in African Food Systems" funded by the Rockefeller Foundation's Yieldwise initiative.

Through this research project, methodological approaches to measure FLW in smallholder supply chains were designed, tested and trialled. Taking actual field measurements is a fundamental precondition to obtain a baseline that serves to inform decision-making with regards to investments to reduce FLW. Identifying the stages in the value chain where losses are more prominent and, the possible root causes associated to these losses, will allow stakeholders to direct their efforts and investments to reduce losses and improve supply chain efficiency in a manner that generates sustained impacts for all stakeholders in the supply chain. By working together with agribusiness companies and smallholder farmers to identify and measure FLW in smallholder supply chains, this research project aims to spur corporate action on FLW reduction by providing methodological guidelines for companies to measure and track FLW throughout their supply chains.

1 https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-12-responsible-consumption-and-production.html

2 https://www.un.org/sustainabledevelopment/development-agenda/

1.1 Objectives and context of this research pilot

The general objectives of this pilot study, as defined in coordination with Olam, were centered around understanding the magnitude and impact of losses occurring in the rice outgrowers initiative in Nigeria with the goal of assessing:

- How much losses occur in the rice outgrower supply chain operated by Olam in Nigeria
- Where the critical loss points are within the different stages in the rice supply chain
- What the impact of those losses might be in terms of economics, resource use efficiency and Greenhouse gases
- Potential investment areas to reduce losses
- Applicability of the measurement approach for business value and replication across other Olam's rice origins

Methodologically this pilot study aims to:

- Understand the primary characteristics of the business environment such as its supply chain and market, sustainability priorities and commitments, and external stakeholders landscape that would bring an agribusiness company to prioritize FLW measurement and investments in FLW reduction
- Develop measurement prototypes that are cost-effective, relevant and practical to facilitate business adoption
- Understand how companies and other stakeholders can successfully work together to reduce FLW in smallholder agricultural value chains
- Understand how FLW measurement and reduction can contribute to companies' sustainability targets for environmental and social issues (For example: decreased GHGs or improved farmer incomes)

By measuring and assessing the losses incurred at different stages of the rice supply chain, the study identifies critical loss point within the chain. The evidence generated through the pilot study can be used to guide strategic investments in improved technologies and practices to reduce loss at these critical points. In the following segment, we will briefly elaborate on the different impacts that loss reduction investments can have.

BOX 1 concepts and definitions:

- **Food loss** refers to the decrease in quantity or quality of food for human consumption throughout the different segments of the food supply chains – production, harvest, postharvest handling, agro-processing, transport, distribution (wholesale and retail), and consumption (based on definition from Save Food Initiative 2015). For this pilot study Rice loss was defined as: "Mature rice that is ready for harvest but not ending up for human consumption".
- **Food waste** refers to discarding or alternative (non-food) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level (FAO, 2014)3. Food waste is recognized as a distinct part of food loss because the drivers that generate it and the solutions to it are different from those of food losses.
- **A supply chain** refers to a network between a company and its suppliers to produce and distribute a specific product to the final buyer. This network includes different activities, people, entities, information, and resources. The supply chain also represents the steps it takes to get the product or service from its original state to the customer.
- **FLW Hotspots** refers to activities or stages in the food life cycle, in which an intervention is required to prevent and to avoid food loss and waste; or to handle it to a level that is even acceptable (Adapted from HACCP by Catalina Giraldo, FAO Consultant (2016)).
- **Critical loss points** are the stages in agri-food chains where FLW is highest, as well as where it has the highest impact on food security, the highest impact on resource use efficiency and the highest effect on the economic result of the Food Supply Chain (Adapted from: Tatlıdil, Dellal, & Bayramoğlu, 2013).
- **Resource use efficiency** refers to the relationship between food system output (fibre, food, bioenergy, environmental services, GHG emissions, water contamination, etc.) and food system input (land, fertilizer, agro-inputs, energy, water, labour, capital, etc.). Improved efficiency entails more food being produced with fewer inputs and less negative environmental impacts (Adapted from: Garnett, Roos, & Little, 2015).
- **Rice** is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). Rice is utilized as an aggregate nomenclature encompassing an array of different cultivars and varieties. The term **paddy** is generally used to refer to rice within the husk, be it in the field or harvested. In this document the term rice is used generically referring to the grain seed with and without the husk.

Reducing losses in Olam's rice value chain can positively affect different stakeholders in the value chain. Nevertheless, each actor is affected differently, be it smallholder producers, farm labourers, Olam Rice Nigeria, consumers or the environment.

For smallholder farmers, reducing harvest and post-harvest losses has the potential to improve their income, enhance their livelihoods and improve the food and nutrition security of their families.

For an agribusiness company such as Olam, that sources from smallholder outgrowers, reducing post-harvest losses can enhance the stability and efficiency of supply and improve the processing output. Increasing the recovery of yield at the production level has a direct benefit on the quantity of volumes processed by Olam at its processing facility.

By reducing on-farm losses, Olam can process and supply larger quantities of rice to the Nigerian market. This is beneficial for Olam's reputation and 'licence to operate'. It also positively strengthens Nigeria's self-sufficiency in terms of rice production and consumption and improves the food and nutrition security of the population whilst reducing the necessity to invest in importing rice from abroad.

In terms of the environment, reducing post-harvest losses in the rice value chain has the potential to directly and indirectly improve the efficiency in terms of utilization of natural resources during cultivation, harvesting, drying, storing, processing, packaging, transporting and marketing of rice, but also in terms of land use. Additionally, reducing losses through improved management practices in rice production and improved post-harvest handling can potentially reduce GHG generated through rice production and decomposition of plant residue.

1.2 Olam Nigeria's Rice outgrower initiative and the context of measuring losses within this pilot study

Olam International is a leading food and agri-business supplying food, ingredients, feed and fibre to customers worldwide. Olam's operations include farming, processing and distribution operations, as well as a vast sourcing network of smallholder farmers.

Olam is a corporate champion in its commitment to address the many challenges involved in meeting the needs of a growing global population3. Through Olam's sustainability framework priority areas have been identified that are geared to achieve three key outcomes:

- **Prosperous farmers and food systems:** Re-designing farming and food value chains so that all players profit fairly from their work
- **Thriving communities:** Re-vitalising rural communities so that the people who produce food, feed and fibre can live well
- **Re-generation of the living world:** Regenerating nature, to restore the balance between agriculture and ecosystems in living landscapes.

In 1989, Nigeria was the launch pad for Olam's global business. From sourcing cashews at the farm gate 30 years ago, Olam Nigeria has expanded into cocoa, sesame, cotton, rice, wheat milling and packaged foods including biscuits, candy, confectionery, juices, beverages, breakfast foods and kitchen ingredients such as tomato paste. For the last 10 years, Olam Nigeria has been the largest non-oil exporter in the country.

The companies' networks throughout Nigeria encompass approximately 500,000 farmers and have created tens of thousands of jobs in indirect employment. In 2013, over 19 billion Naira was invested in a 10,000-hectare farm with integrated mill which directly employs 950 people from the surrounding communities, producing 60,000 metric tonnes of rice for the Nigerian markets. The farm also supports

[3] Source: Olam, 2019. Corporate Factsheet 2019. https://www.olamgroup.com/content/dam/olamgroup/about-olam/at-a-glance/at-a-glance-pdfs/corporate_factsheet_eng_feb_2019.pdf

an 'outgrower programme' whereby surrounding rice-growing communities are supported by the Olam farm with training, pre-finance, fertiliser and seeds in order to improve their paddy yields. Olam's rice outgrowers model is referred to as the Rice Nucleus model[4]

Currently 22,700 farmers are engaged in the programme. This investment is specifically in line with the Government's Agricultural Transformation Agenda to produce rice for the domestic market thereby boosting self-sufficiency. In 2013, it was internationally recognised by The Rockefeller Foundation as a catalytic innovation' in African Agriculture' and in 2018, it has been identified as one of 3 high impact success stories for Global Recognition by the United Nations Economic & Social Council.

Olam, in partnership with IFAD and the Federal Government of Nigeria (FGN) established The Value Chain Development Program (VCDP) in 2015, to improve the livelihoods of smallholder rice farmers in Nigeria by increasing food security, creating jobs and opening market access.

It works to connect smallholder farmers to markets, land, credit and other agricultural support to improve productivity, the quality of their produce and their linkage with agro-processors for the buying of this produce. In turn, this supports the Government's ambition to transform agriculture into a profitable venture for young people and boost domestic food security.

The collaboration under VCDP brings mutual benefits – providing rice smallholders in Nigeria with support, allowing them to be more productive means they increase their incomes, while consistent and high-quality supplies of rice are making a significant contribution to national priorities on import substitution and food security[5].

Olam is committed to minimize crop and product losses to improve food availability and reduce emissions globally. Olam has partnered with UN environment (UNEP) and the International Rice Research Institute (IRRI) on the Sustainable Rice Platform (SRP) as a governing member to define internationally accepted, scientific solutions to the climate impacts of rice agriculture. Across Olam's directly managed farms, processing and logistics operations, the company follows waste management procedures in accordance with regulations and actively encourages the reduction of waste from all aspects of the site operation. At a sector level, Olam's ambition is to collectively halve food loss by 2030. Olam is co-lead of crucial sector alliances such as Champions 12.3, the Global Agri-business Alliance (GAA) and the World Business Council for Sustainable Development (WBCSD) most notably their Climate Smart Agriculture, Food Reform for Sustainability and Health (FReSH) programs. The company sees FLW reduction as an opportunity for smallholder farmers to increase their return on investment, with the ability to sell larger volumes.

Olam has recently committed to halving postharvest food loss and waste in their rice operations by 2030[6]. Olam CEO Sunny Verghese, recently announced the new initiative from the Sustainable Rice Platform, putting the spotlight, for the first time, on reducing food loss and waste in the rice industry. For Olam, this means working towards a 50% reduction of on-farm and near farm rice losses by 2030, with an immediate focus on establishing targets, ongoing measurement, and identification of meaningful interventions, under the Champions 12.3 Target-Measure-Act framework. According to the announcement, made on the side-lines of the UN Climate Action Summit and UN General Assembly in New York, a task force will be set up to support committed stakeholders in the rice sector to "identify hotspots, develop a roadmap to improve farming methods, tackle rice loss and waste across the supply chain, identify strategies to accelerate change and monitor industry actions to work towards achieving the 50% reduction target.

4 https://b.3cdn.net/rockefeller/ec261fef99375f2ee5_n8m6bksd9.pdf

5 https://www.olamgroup.com/products/food-staples/rice.html

6 http://www.sustainablerice.org/assets/docs/Sustainable%20Rice%20Platform%20Calls%20upon%20Rice%20Industry%20to%20Halve%20Rice%20Loss%20and%20Waste%20Worldwide.pdf

1.3 Rice production and consumption and its environmental impact

Rice is the staple food of more than half of the world's population[7]. The vast majority of rice is grown on smallholder farms on areas extending from 0.5 to 3 hectares.

According to leading rice research organizations, rice is the fastest growing staple food in sub-Saharan Africa[8]. Annual per capita rice consumption has doubled since 1970 to 27 kg and continues to increase rapidly in most countries, caused by high rates of population growth and changing consumer preferences. Urban dwellers who rarely ate rice only a few decades ago now consume it daily. In African countries, such as Nigeria and Tanzania, thanks to rising incomes and related changes in dietary habits, people are moving away from tubers and cassava to rice[9].

According to the International Rice Research Institute (IRRI), post-harvest rice losses in Africa and Southeast Asia generally range from 10% to 30%, caused by loss in weight through spillage, losses to pests, low milling yields, inappropriate postharvest management practices, delays in the postharvest chain, outdated postharvest equipment and infrastructure, and low operators' skills. According to this source, reducing post-harvest losses in the rice value chain is a clear opportunity to increase the productivity of smallholder farmers, improve farmers' incomes, improve food security and reduce the environmental impact of rice production[10].

Rice is one of the world's most water demanding agricultural commodities due to the extent and magnitude of rice production and the high water demand during production. Furthermore, rice cultivation is a significant source of man produced methane. According to the Sustainable Rice Platform[11], rice is the daily staple for more than 3.5 billion people, accounting for 19% of dietary energy globally; rice provides livelihoods for over 1 billion people; rice is produced on 160 million hectares, predominantly by 144 million smallholders; rice uses 34-43% of the world's irrigation water for production and rice is responsible for up to 10% of global methane emissions.

The impact of rice production on methane emissions is mainly attributed to the periods of water logging during production and to emissions generated from the biomass that decomposes in fields. Reducing post-harvest rice losses and improved crop residue management in the rice value chain has the potential to improve resource use efficiency (land and water) and reduce GHG emissions significantly.

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7 http://ricepedia.org/rice-as-food/the-global-staple-rice-consumers
8 http://ricepedia.org/rice-around-the-world/africa
9 Rice Almanac: http://books.irri.org/9789712203008_content.pdf
10 Rice Almanac: http://books.irri.org/9789712203008_content.pdf
11 http://www.sustainablerice.org/Resources/

1.4 Overview of stakeholders within Olam's rice outgrowers initiative

The rice supply chain in scope for this pilot is composed of different stakeholders who each perform a series of activities and functions within the different stages of the value chain.

Figure 1 provides a summarized overview of the different stakeholders involved in the rice value chain of Olam's rice outgrowers initiative in Nigeria and the functions they perform.

VALUE CHAIN ACTOR	***•ACTIVITIES AND FUNCTIONS PERFORMED***
Farm laborers	• Provision of farm labour (land preparation, planting, irrigation, weeding, harvesting, threshing, winnowing, bagging, loading, transporting)
Smallholder outgrowers	• Provision of productive assests (land, capital, experience) and work opportunities in rice farming • Lead entrepreneur supplying quality rice to Olam
Input providers	• Seed providers • Fertilizer companies
OLAM field support staff	• Technical guidance and support to farm managers during rice production cycle • Farm level extension services including Good Agricultural Practice (GAP) training • Provison, distribution and sales of quality seeds and agro-inputs • Distribution of credit and loans • Provision of access to central aggregation centre (warehouses)
Truck drivers	• Transportation services to move paddy bags from the warehouses to the processing mill
OLAM rice milling plant operators	• Offloading paddy bags from trucks. As the paddy enters the mill, the quality control takes place and the paddy gets graded. The paddy is processed into rice and then packaged. For quality rejects, vouchers are issued.
Olam central office staff	• Coordination of logistics, handling, transporting and distribution of processed and packaged rice • Research and development for improved productivity
Retailers	• Distribution and selling of rice
Consumers	• Buy and consume processed rice
Public sector	• National and regional authorities coordinate with Olam, outgrowers and local governments to facilitate and support the production of rice for the domestic market and reduce reliance on rice imports

Figure 1 *Overview of stakeholders in the rice supply chain*

2 Method

2.1 Participatory development of measurement methodology

Based on conversations with Olam staff, WUR pre-designed a FLW measurement methodology in compliance with the World Resources Institute Global Food Loss and Waste Accounting and Reporting Standard[12]. The measurement methodology was contextualized and specifically designed for this pilot, taking Olam's interests and project objectives into consideration. Olam expressed an interest to get a better understanding of the losses that occur in their smallholder outgrower scheme focussing on specific stages including harvest, post-harvest, threshing, winnowing, storage and transport losses.

Before initiating the pilot during peak harvest season, the measurement methodology was reviewed, tested and validated though a participatory kick-off workshop and a real life field trial. Stakeholders involved in this workshop included smallholder farmers, women group leaders, Olam management team and, Olam field coordinators from the Olam rice outgrowers initiative operating across three states: Taraba, Plateau and Benue. The field trial and the collective review of the measurement methodology provided valuable input to recalibrate some elements of the approach and help coordinate the pilot activities with the Olam team and the consultants involved in field data collection. This process is illustrated in the figure and pictures below.

Figure 2 *Steps in methodological process of pilot Study*

Picture 1 *Activities during stakeholder engagement workshop*

12 WRI. Food Loss and Waste Accounting and Reporting Standard. https://www.flwprotocol.org/wpcontent/uploads/2017/05/FLW_Standard_final_2016.pdf

2.2 Description of measurement methodology and data collection process

For the pilot, data were collected from a total of sixty farms that were randomly selected from three different regions in Nigeria; Benue state, Plateau state and Taraba state. Twenty farms were selected per state.

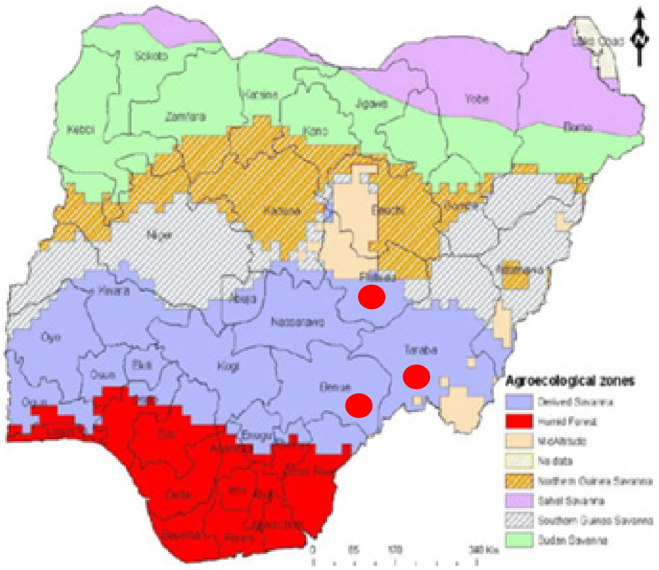

Figure 3 *Nigeria's main agro-ecological zones and the three states where the pilot was conducted*

The scope of this pilot study includes activities in the supply chain from harvesting till milling. Figure 4 portrays a flow chart of the different activities in the rice supply chain of Olam Nigeria and indicates the potential losses per activity

For this pilot study, loss of rice is defined as: "Matured rice that is ready to harvest but not ending up for human consumption". Human consumption has been defined as "rice sold by Olam". Direct measurements of rice loss are used for the on-farm activities up to the point where rice arrives at Olam collection centres.

Olam Nigeria already monitors data on losses and product value streams daily, from the point when rice arrives and is received at Olam collection centres up to the milling process. At the stages where Olam was able to provide data, direct measurements were not performed and Olam's data were utilized.

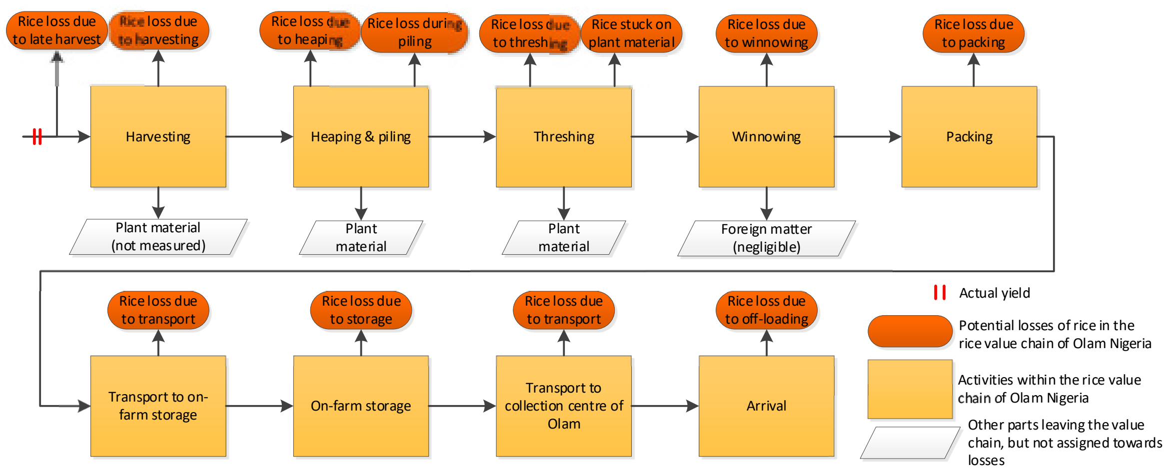

Figure 4 *Flow chart of a part of the rice value chain of Olam Nigeria*

Direct measurements were conducted at the 60 farms. At each of the 60 farms, three individual rice samples were taken from a demarcated plot of $1m^2$ located at different sites within the respective rice field. In total 180 (60*3) rice samples were tracked and followed as they moved though the supply chain up to the point of arrival at Olam collection centres. The weight and moisture content of the samples were measured before and after each activity stage. Once the samples arrived at the packing stage, the samples were packed in bags and the sample unit was converted to the filled bag of rice.

To complement information obtained from the direct field measurements, observations were documented, and surveys were conducted with the 60 selected farmers before direct measurements were taken. Survey questions focussed on the farmer perception and his experience based on the previous year to learn more about the causes around rice losses, farmer's estimation of losses and the destination for rice losses. The questions were asked in reference to the different stages in the rice supply chain. The methodology for the direct measurements to measure the potential losses per activity is described in detail below. In figure 6, a part of the data registration form is presented. This form is used to record the data obtained during the direct measurements. A step-by-step approach methodologically describes how to collect and record data correctly.

2.2.1 Harvesting

For this pilot, harvest losses are defined as: the losses that occur due to late harvest or harvesting activities. Before harvesting, overripe rice can be released by the plant (shattering). At harvest, the entire rice stalk is harvested with the panicle attached to the stalk. The movements associated with the harvest activity can cause rice to detach itself from the panicle and fall on the ground. All rice that falls on the ground is considered as harvest loss. This loss was measured by picking up and weighing the rice obtained from each of the $1m^2$ sampled fields. The sum of the harvest loss and the harvested rice is considered as the actual yield.

As the harvested rice is attached to the plant material at this stage, both rice and plant material were weighed together and subsequently the values were corrected taking into account the weight of the plant material calculated during the data analysis. The moisture content of the rice that was lost and the rice that continued on to the next activity was measured and recorded.

2.2.2 Heaping and piling

Heaping is defined as the movement of plant material (and attached rice) from the location where harvesting took place to the location where harvested rice is heaped until it is threshed. Piling is defined as the waiting time between harvesting and threshing.

Once rice is harvested, the rice stalks are transported by hand to the location where threshing is to take place. Rice stalks are bundled immediately after harvesting, then transported by hand and put on a pile at that new location. During this activity, losses occur when the plant releases rice as a result of the movement of large bunches of stalks carried from one location to another by hand (shattering). The difference in weight at the harvest location (a) compared to the final heaping location (b) is a combination of loss of rice and loss of plant material. This value is corrected, during the data analysis, in order to take into account the loss of weight due to lost plant material. In this pilot, the rice lost during this movement is defined as: loss due to heaping (see figure 5).

If required, once the harvested stalks are heaped, the rice is left in the field for a specific period of time to dry and lower the moisture content. Losses may occur during this drying stage. To assess the amount of losses during this drying activity, the rice and plant material were weighed before and after the drying stage. The difference in weight can be attributed to a combination of lost rice, reduced moisture content and loss in plant material. During data analysis the data is corrected to take into account the weight loss due to lost plant material and reduced moisture content (see figure 5).

By combining and adding the values of rice lost during heaping (on-farm movement) and rice lost during piling (drying time) the total loss of rice for this activity was calculated. The moisture content was measured before the start of the heaping and piling activity and both after heaping and after piling.

Throughout this report we will refer to these two activities with the term heaping.

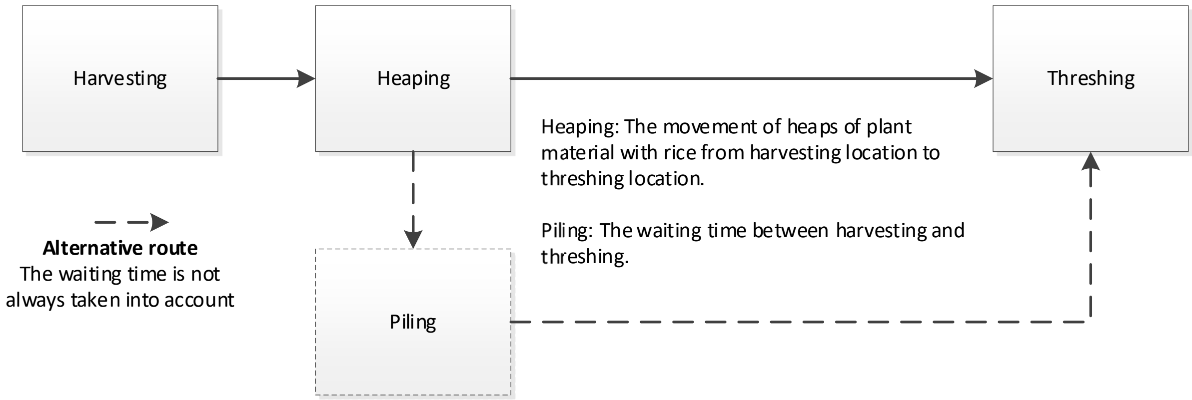

Figure 5 *Methodology to measure loss during the heaping and piling activity*

2.2.3 Threshing

During threshing, the heaped and piled plant material including the panicles containing rice grains, is threshed. During this activity, the rice will be separated from the plant material by beating it with force.

Losses occurring during threshing have two root causes. Firstly, losses are incurred when rice grains shoot away as a result of the beating-movements during threshing and disappear into the field. This loss is measured by calculating the difference in weight of the plant material before and after the threshing activity. Secondly, during threshing, not all of the rice grains become detached from the panicles. The rice grains that remain attached to the panicle and stalk are a second source of loss during threshing. For this pilot, all the rice-grains that remained attached to the plant material were manually separated from the plant material and weighed. The total losses in rice incurred during threshing are calculated by adding up these two types of loss. The moisture content was measured for both successfully threshed rice and rice that remained attached to the plant material.

2.2.4 Winnowing

During winnowing, different types of foreign matter (impurities, small stones, straw and other plant material) are removed from the rice grains. The technique used in this activity is to drop small amounts of rice from a certain height onto a tarpaulin allowing the wind to blow away the foreign matter as it falls. The weight of foreign matter that can be blown away by the wind is very small and negligible with respect to the weight of the winnowed rice. Therefore, this weight is not taken into account. The measurement approach takes into account the difference in weight of rice grains before and after the activity, considering that value as loss generated during winnowing. The moisture content of the rice grains was measured before the start of the activity and after ending the activity.

2.2.5 Packing

In this activity, the winnowed rice is packed into bags. Within this pilot, the considered sample size was a field surface area of 1m^2, the amount of rice obtained from this 1m^2 would never fill a complete bag. Therefore, this activity was split up. First, the weight of an empty bag was determined. Secondly, the winnowed sample of rice grains was put in that empty bag and weighed again. The difference in weight was assigned to rice loss incurred during packing of the sample. The second step was to fill the bag completely with other rice harvested from the farm. Rice that did not end up in the bag, but on the ground, was picked up, weighed and recorded as loss. During the data collection these two steps are combined. The sum of the two values was considered as loss incurred during packing.

2.2.6 Transport to on-farm storage

Once the rice is packed into bags the sample size changed from a field surface area of $1m^2$ into the fully loaded bag. The difference in weight of the bag before and after the transport activity is considered as loss. Similar to the previous activities, during this stage the moisture content of the rice was measured and taken into account when calculating the losses.

2.2.7 On-farm storage

During on-farm storage, losses are measured based on the weight of the fully filled bag. The difference in weight of the bag before and after storage is considered as loss. The moisture content of the rice was measured before the start of the activity and after the activity.

2.2.8 Transport to Olam collection centre

During transportation from the farm gate to the Olam collection centres, losses were measured based on the weight of the fully filled bags. The difference in weight of the bag before and after transport was considered loss incurred during transport. Again, the moisture content was measured before and after the activity.

Upon arrival at Olam collection centres, the sampled bags receive a quality check by Olam. Olam staff check the bags of rice for percentage of good rice, immature rice, red rice, empty shells and foreign matter. In case the rice in the bag is of too low quality, the complete bag can be rejected. Final payment for the received rice is formalized at this stage in relation to the volumes and quality of the received rice.

2.2.9 Replicating real life scenarios with a standardised measurement protocol

Rice harvesting and post-harvest procedures vary from farm to farm. Similarly, the specific time between each activity can also vary from farm to far such as the manner that rice is handled between activities. For example, the heaping of rice usually starts only when the entire rice field has been harvested. Similarly, threshing only starts once all the has reached the optimal moisture content during the heaping and piling stage. Between each activity there is a waiting time period where the rice is not touched before the next activity initiates. The measuring methodology follows the rice samples through the entire process by taking this waiting time into account to replicate field conditions where feasible. During the data collection that took place for this pilot the waiting time between activities did not always replicate real-life scenarios. Due to varying times of activities between farms some data related to on-farm storage was not collected. These data related issues are described in detail in Chapter 5.

2) Harvest:

a) Harvest a random plot of 1m² at the usual harvest method. Just do it as usual. (See paper 'how to' how to make the plot of 1m²).

b) Weigh the harvest (including plant) of this 1m² and write down the weight in kg (=H1).

c) Measure the moisture content of the paddy in the plant (=H1m).

d) Collect and weigh all paddy from the ground located in that specific plot (=H2).

e) Measure the moisture of the paddy on the ground (=H2m).

f) Do this for the 3 samples taken in harvest stage.

3) Heaping and piling

a) Weigh the harvested sample of the 1m² again. (=H1p)
When heaping and piling happen immediately after harvest, then this is not needed. When drying is taking place before heaping and piling then needed.

b) Measure the moisture content of the paddy in the plant before heaping and piling (=H1pm)
When heaping and piling happen immediately after harvest, then this is not needed. When drying is taking place before heaping and piling then needed.

c) Take all the material from H1h to the piling place and weigh it (=P2).

d) Measure the moisture content after piling (=P2m).

e) When drying in this stage, please weigh again after drying (=P3).

f) If applicapble, measure the moisture content after drying (=P3m).

g) Do this for the same 3 plots of 1m².

4) Threshing:

a) Write down again the weight of the plant + paddy as in step 3 Heaping and piling (=P2t).

b) Do the threshing as usual. For all the material from the 1m² plot. Don't push it to get all the paddy off. Just act as normal.

c) Collect the paddy that is succesfully threshed and weigh this (=T1).

d) Measure the moisture content of this paddy (=T1m).

e) After that take all the paddy from the plant. Then you have 2 categories: Paddy from the plant material (=T2) and plant material (also from ground) (=T3) and weigh both T2 and T3.

f) Measure the moisture content of the paddy (=T2tm).

g) Do this for the same 3 plots of 1m².

5) Winnowing:

a) Write down again the weight of the paddy that was succesfully threshed (=T1) and write it down again before you start winnowing (=T4w).

b) after winnowing, weigh the winnowed part again (=W2)

c) Measure the moisture content of the succesfully winnowed paddy (=W2m).

d) Do this for the same 3 plots of 1m².

6) Packing:

a) Write down again the weight of the paddy that was successfully winnowed (=W2) and write it down again before you start packing (=W2p).

b) Weigh the empty bag (=Pa2). After that fill the empty bag with the paddy of 1m² and weigh it again (=Pa3).

c) Fill the rest of the bag with other paddy of your harvest (do not include one of the selected plots, but use another part of your field to fill the bag as usual.

d) Measure the moisture content of the paddy in the bag (=Pa3m).

e) After filling the bag as usual, close it and weigh this bag (=Pa4) and tag the bag.

f) Collect all paddy that has fallen around the bag on the ground. Weigh this paddy (=Pa5).

g) Do this for the same 3 plots of 1m².

TIME schedule

	Harvest		Heaping and piling		Threshing		Winnowing		Packing
	harvest starts (entire harvest)		heaping and piling starts (entire harv		threshing starts (entire harvest)		winnowing starts (entire harvest)		packing starts (entire harvest)
date	8/11/2018	date		date		date		date	27/Nov/18
time	3:32PM	time		time		time		time	1:33 PM
	harvest ends		heaping and piling ends		treshing ends		winowing ends		packing ends
date		date		date		date	8/11/2018	date	27/Nov/18
time		time		time		time	3:54PM	time	1:58 PM

2. Harvest

		surface (m²)
INPUT		
F1	plant material / Paddy	1
		weight (kg)
OUTPUT		
H1	cut plant material / Paddy	
H2	Paddy on the ground	

3. Heaping and piling

		weight (kg)
INPUT		
H1p	Plant material / Paddy	
Output 1		
P2	Plant material / Paddy	
Output 2 (if applicable)		
P3	plant material / Paddy	

Or

4. Threshing

		weight (kg)
INPUT		
P2t	cut plant material / Paddy	
OUTPUT		
T1	Succesfully threshed paddy	
T2	paddy in plant material	
T3	from ground)	

5. Winnowing

		weight (kg)
INPUT		
T4w	Paddy ready for winnowing	
OUTPUT		
W2	Paddy	

Remark: if winnowing is done in such a way that paddy with hull, that are processed away from the end product, can be collected easily, this should be done and weighed. This might be difficult if e.g. strong ventilation is used. That is why this flow is not part of the scheme.

6. Packing

		weight (kg)
INPUT		
W2p	Paddy	
OUTPUT		
Pa2	Empty bag	
Pa3	bag / Paddy in bag	
Pa4	Completely filled bag	
Pa5	Paddy around bag	

MOISTURE

		Moisture %
H1m	cut plant material / paddy	
H2m	paddy on the ground	
H1pm	Plant material / Paddy	
P2m	Plant material / Paddy	
p3m	plant material / Paddy	
T1m	Succesfully threshed paddy	
T2m	Paddy from plant material	
W2wm	Paddy	
Pa3m	paddy	

Figure 6 *Data registration form and measurement methodology*

2.3 Data analysis

2.3.1 Calculations

Data analysis was conducted based on the completed data registration forms (see figure 6), surveys and observations registered by the consultant team. For the data analysis obtained from direct field measurements, descriptive statistics was used in Microsoft Excel.

With data collected during the threshing stage, the ratio between rice and plant-material is determined per sample during data analysis. This ratio is used in the analysis to calculate the weight of the rice in the harvesting and the heaping activity.

All calculations were performed from tracking the three samples obtained from the $1m^2$ sample plots from each of the 60 farms. Hence all results can be presented at the individual farmer level. In the next chapter results are presented as an average of all individual farms, and as an average of the individual farms located in the three regions respectively.

2.3.2 Moisture content

Throughout all activities, the moisture content of the rice sample was measured. Methodologically, this allowed to differentiate between differences in weight caused by loss in moisture and differences in weight caused by food loss.

Moisture content was measured using a moisture meter. At every step of the measurement protocol, three moisture content measurements were taken; the average of three was recorded as the moisture content of the rice. During each step and activity, the moisture content was measured before initiating the activity, from the rice that was lost (when collected), and the rice that continued on to the next activity.

As reference of how moisture content calculations were systematically embedded in the methodology and calculations of this pilot study, figure 8 depicts an example of the methodology to calculate rice losses generated during the harvesting activity.

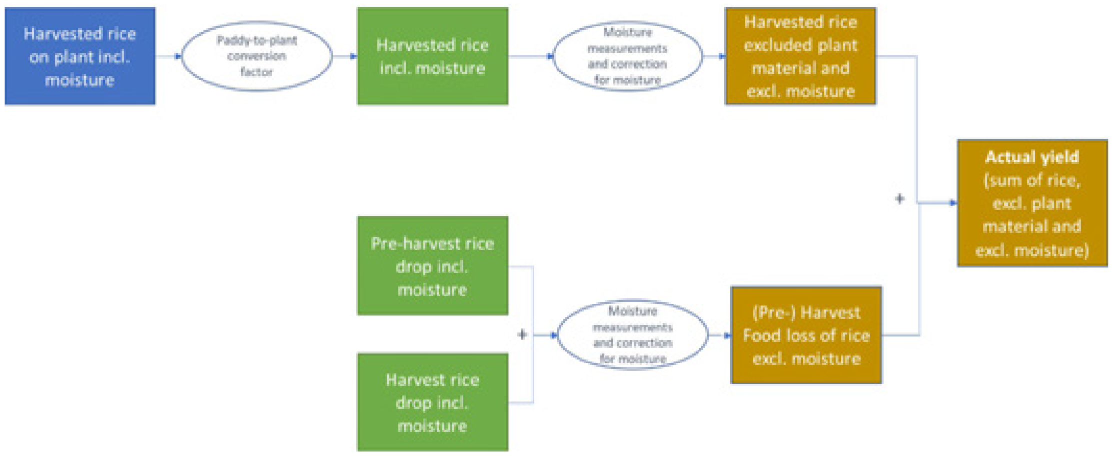

Figure 7 *Methodology to measure yield and losses during the harvest activity*

3 Results

3.1 Supply chain losses at farm level

Table 1, shows the percentage of loss for every activity separately for the different regions. In this table, the losses between activities are not connected. For example, the 6% loss during heaping in Benue state is based on the loss during heaping and the input of rice for this activity. This table shows that harvesting and threshing resulted in the highest losses when looked at per activity. For Plateau state and Taraba state the highest losses were attributed to threshing, while in Benue state the highest losses occurred during winnowing.

Table 1 *Losses (in % of input activity) per activity for the different regions (*)(**)*

	Benue	Plateau	Taraba	Average for all regions	Deviation
Harvesting	11%	15%	9%	12%	0% - 29%
Heaping	6%	4%	1%	4%	0% - 21%
Threshing	11%	18%	11%	13%	3% - 44%
Winnowing	15%	10%	6%	10%	0% - 33%
Packing (based on observations and measurements)	0%	0%	0%	0%	0% - 0%
Transport to Olam collection centres	0%	0%	0%	0%	0% - 0%

(*) waiting times are not included

(**) Data on transport to on-farm storage and on-farm storage were not available

The average loss for the harvesting activity in this pilot is 12%, with deviations between 0% and 29% for individual farms. Both the lowest and the highest losses were measured in Plateau state. A possible cause for these losses can be the mature state of the rice at the time of harvest.

The average loss for the activity heaping is 4%, with deviations between individual farms ranging from 0% to 21%. The highest loss was recorded in Plateau state and the lowest losses in Benue state and Taraba state. At the farm that recorded the highest losses, rice and plant material was moved by hand, without the use of tarpaulins, over a distance of four meters from the place where it is harvested to the place where it is heaped and piled. Data does not include waiting time.

The average loss for the activity threshing is 13% and deviates between 3% and 44%. The highest loss for threshing can be found in Plateau state and the lowest loss in Taraba state. Based on the observations and interviews, no differences can be found between those two farms in the way and manner that rice was threshed.

The average loss for the stage of winnowing is 10%. Measurement data deviated between 0% and 33%. The highest loss can be found in Benue state and the lowest losses in Plateau state. Five farms in Plateau state recorded no loss during winnowing.

Observations recorded by the field team concluded that no loss occurred during packing. Therefore, the loss was accounted as 0%. The bags, including the samples, were fully filled with winnowed rice. Rice that did not end up in the bag, but on the ground, was considered as loss. Only 2 samples recorded losses during packing. These losses were minimal measuring less than 0.1% loss.

The average loss for the stage transport to Olam collection centres is 0%. No losses were found for this activity.

3.1.1 Average losses for the entire value chain

The percentages described above were based on the input per activity and stage. The following results illustrated below, are presented as a percentage based on the actual yield. The actual yield is a sum of all matured rice that was harvested and all rice collected as loss at the harvesting stage. In total, the average loss of rice for the three states from the point of harvest up to the transportation stage was found to be 34%. For Benue state it was 37%,For Plateau 39% and 25% for Taraba state (see figure 8).

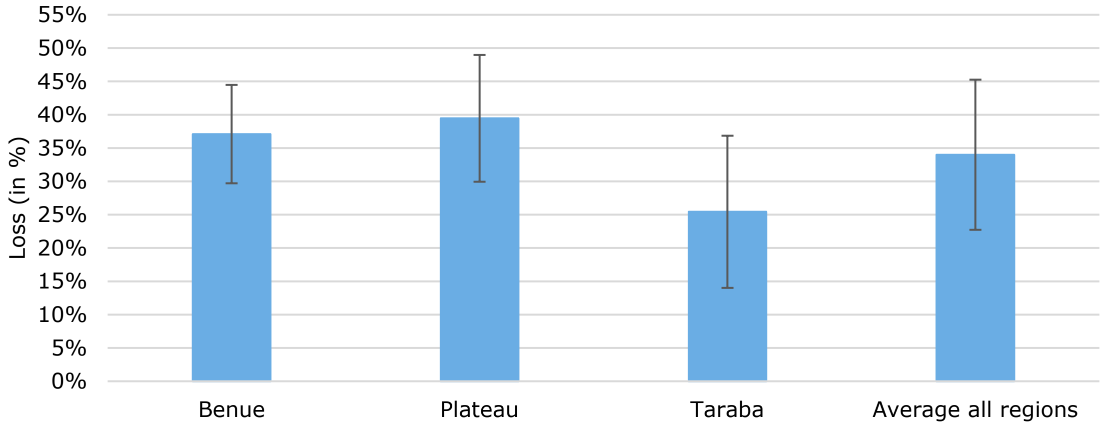

Figure 8 *Average loss (as % of actual yield) and standard deviation per region for harvest until packing initiates*

In figure 9, the total loss, from the point of harvest up to the winnowing stage, is provided for all sixty individual farms specified per state; Benue state, Plateau state and Taraba state respectively. The individual farms within each state are located at random in the figure. High variation between states is recorded. The losses in Benue state varied between 22% and 51%, for Plateau state losses varied between 24% and 55% and for Taraba state between 8% and 48%. This variation might indicate how specific farm management practices and specific timing of activities can significantly affect the extent of losses. These variations are similar to those found in literature on FLW. The scatterplot highlights that 5 of the 60 data points registered losses above 50%, whilst one third of the data points (20 out of 60) registered losses above 40%; 5 out of the 60 data points, registered losses below 20%.

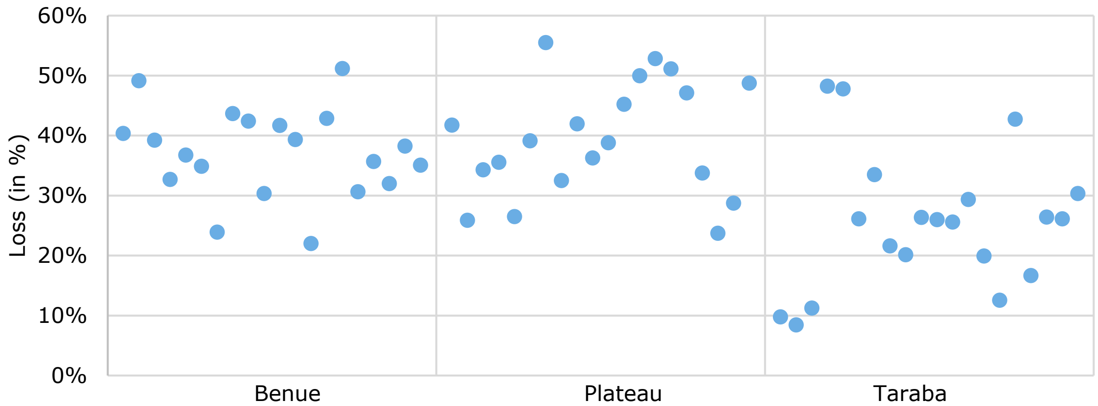

Figure 9 *Total loss (as % of actual yield), including harvest, heaping, threshing and winnowing, of individual farmers in the three states*

Figure 10 shows how the losses are built up per value chain activity, based on relative numbers.

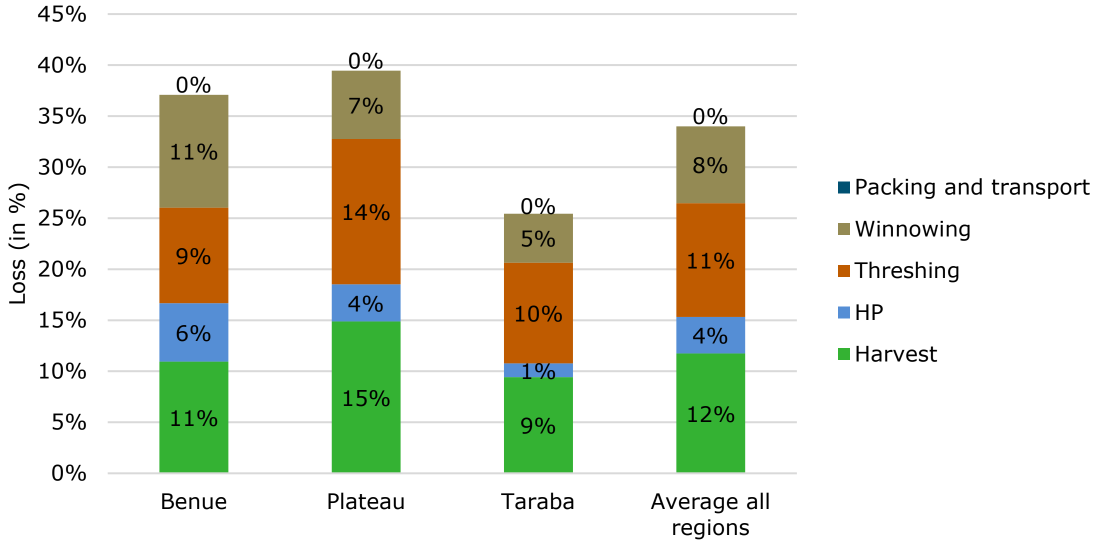

Figure 10 *Average loss (in % of actual yield) per region from point of harvest to packing, based on the different activities*

Figure 11 illustrates the amount of rice (in % of actual yield) that is effectively moving to the next stage in the supply chain, differentiated per region. As the duration of the individual activities is not measured over time, this figure is only based on activities in the value chain.

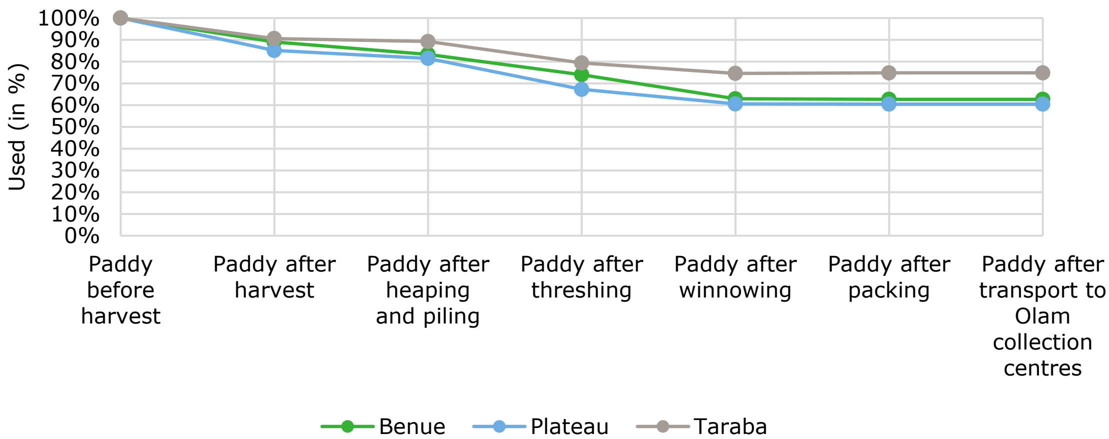

Figure 11 *The amount of rice (in % of actual yield) that is going to the next stage in the value chain per region*

3.1.2 Losses at the milling operations

The rice that is delivered to the local collection centres is then transported to Olam's milling facility. At the mill, the rice is processed. For each 100 metric tons of rice, 67 metric tons are converted into edible rice. For the remaining 33%, 3% is rejected rice, with by-products consisting of 24% husks and 6% bran[13]. Throughout its processing operations, Olam monitors data on losses and product value streams daily. For the purpose of this report, data on losses within processing operations provided by Olam were used.

[13] Source: Based on secondary data received from Olam from two Olam rice mills processing outgrowers' produce

3.1.3 Self-reported losses

A number of survey questions focussed on farmers self-assessment of losses at different stages in the supply chain. Survey questions specifically requested farmers to estimate losses, based on their perception from the previous year. To describe the losses, estimates and references were used such as: units or bags of rice; for example a quarter of a bag or half a bag. Responses were, converted into numbers keeping the weight of the original reference in consideration, as different bag sizes exist based on market availability and farmer preference.

An important observation about this was that during the measurements, the average bag weighed 128 kg, varying from 120 kg to 140 kg. However, from the survey responses, the average bag weight was 107 kg, varying from 50kg to 150 kg. Furthermore, in the interviews, farmers indicated that last year they harvested in the range of 9 to 60 bags of rice per hectare. These discrepancies raise concerns regarding the framing and understanding of questions that were asked and the value of the responses obtained. For farmer surveys looking to gather quantitative information, field enumerators should be made aware of the typical regional yields in advance of the interview to prevent avoidable data collection errors.

In table 2, below, losses based on direct field measurements and those self-reported by farmers are shown. For losses self-reported by farmers, estimates of losses during packing, transport and storage were included in the farmer survey. Losses directly measured in the field were calculated from the point of harvest to the winnowing stage only.

Table 2 *Total loss (in % of yield) measured versus self-reported*

	Benue	Plateau	Taraba	Average all regions
Measured (% based on actual yield in field)	37%	39%	25%	34%
Self-reported (% based on expected yield + losses)	7%	7%	8%	8%

The percentages of loss per specific activity are shown in table 3. In this table, the percentages of loss derived from the farmers surveys are compared with the results based on the direct measurements. Loss estimates derived from farmer surveys are significantly lower than the results based on direct measurements. **It can be concluded that farmers underestimate their losses. It is possible that farmers somewhat accept their losses as part of their farming process and that they do not have a clear picture of the total extent of losses occurring throughout the different harvesting and initial handling activity stages.**

From a methodological perspective, it can be concluded that self-reporting of losses in smallholder supply chains does not provide a rigorous picture of the extent and stages where losses take place. Direct field measurements provide valuable and insightful information although they require more investment.

Table 3 *Self-reported versus measured losses (in % of input activity) for the different activities*

	Benue		Plateau		Taraba		Average all regions	
	Reported	Measured	Reported	Measured	Reported	Measured	Reported	Measured
Total Harvest loss	3%	11%	3%	15%	2%	9%	2%	12%
Heaping & piling loss	1%	6%	2%	4%	1%	1%	1%	4%
Threshing loss	2%	11%	2%	18%	1%	11%	1%	13%
Winnowing loss	1%	15%	1%	10%	1%	6%	1%	10%
Packing loss	1%	0%	0%	0%	0%	0%	1%	0%
Transport to farm storage loss	1%	-	1%	-	1%	-	1%	-
On-farm storage loss	1%	-	1%	-	1%	-	1%	-
Transport to Olam collection centres loss	0%	0%	0%	0%	1%	0%	0%	0%
Rejects loss	0%	-	0%	-	0%	-	0%	-

3.2 Qualitative surveys

Qualitative data was obtained from the 60 interviews conducted with individual farmers from the 3 different states.

95% of the 80 farmers interviewed were males. Most farmers have more than 5 years of experience in rice farming, with Faro 44 rice variety being predominantly used. In Plateau and Taraba, some farmers use alternative rice varieties including for example: Faro 46, Faro 52, Faro 60, Faro 61, Nerica 8 and L19. From the interviews, it was observed that most rice farms have a surface area of approximately 1 hectare. This was not measured directly but informed through discussions with the farmers. Even though the largest majority of rice is produced on fields of 1 hectare on average, some farmers cultivate rice on plots ranging from 3 to 5 hectares. A very small proportion of farms (2.5% of the 60 sample farms) cultivates rice on plots of 20 hectares.

Based on the findings from the qualitative surveys, a couple of points could be identified where a direct correlation can be made between the variables considered and the losses measured allowing identification of root causes of loss.

There is a potential correlation regarding the farmers that have been trained on Good Agricultural Practices (GAP) and the losses measured. Plateau State where a high level of losses was measured is also where fewer farmers report to have received GAP training. Further analysis could reveal if there is a direct correlation between sensitisation on GAP training and reduced losses at the farm level.

There is one other potential correlation regarding the size and condition of the tarpaulin used during the threshing activity and the losses generated. Further measurements targeted around threshing would be needed to gather more evidence. Yet, if this assumption is confirmed, there would be a strong case for **widespread utilization of tarpaulins during harvesting, during threshing and for any manual transport of rice from one field location to another.** This represents an opportunity to implement a low cost intervention to reduce on-farm post-harvest losses across multiple activity stages.

The survey highlighted that some farms use crop residue, by-products, and rice that does not meet quality requirements (i.e. stalks, fallen grains, rejects) for alternative use such as animal fodder or domestic consumption respectively.

4 Conclusions and Recommendations

4.1 Overview of food loss within the rice value chain, critical loss points and root causes

Overall, this pilot study has documented an average **loss of 35% across the rice supply chain** of Olam Nigeria from point of harvest to packing. The variation of results between farms was high and ranged between 8% and 55%. The variation of results was also high across the three states sampled. The strong variability of loss observed on-farm raises questions on the potential root causes. With further field trails, specific root causes of loss could be highlighted along with best post-harvest management practices. A more granular level of behavioural insight could inform practical and cost-effective innovation that have potential to be adopted by farmers.

Data from this pilot study indicate two critical loss points where the highest levels of loss were measured:

1. Losses generated during **harvest (12%)**
2. Losses generated during **threshing (11%)**

Root causes of loss were attributed to:

- Shattering of rice grains in the field before harvest
- Shattering of rice grains in the field during harvest
- Shattering and loss of rice grains during transportation from harvest to drying location
- Shattering and loss of rice grains during transportation from drying station to threshing location
- Loss of rice grains during threshing

The methodological approach in this pilot, made use of a combination of direct measurements, observations and survey questions. Variability of results was high between directly measured losses and losses estimated by farmers. It is assumed that smallholder farmers are not fully aware of losses incurred and tend to underestimate them. Through their participation in the pilot, farmers and farm labourers were progressively sensitised to the effect rice losses have on their income. As the measurement approach breaks down direct field measurements into specific activities within the production cycle and supply chain, it is comprehensive and tangible for smallholder farmers to see how much loss is occurring and what is being measured.

Many farmers mentioned that measuring losses as part of this pilot made them more aware of the losses they were incurring and that they were optimistic that significant reductions could be achieved by making minor farm management changes. Being able to demonstrate how much rice is lost through direct measurement is effective as part of a sensitisation effort on post-harvest loss reduction, which can later be translated into the adoption of cost-effective practices.

Based on the results of this pilot, it can be concluded that investments to reduce rice losses should predominantly focus on reducing losses occurring during the two critical loss points, namely <u>harvest</u> and <u>threshing.</u>

Reducing losses has the potential to:

- Improve farm productivity and potentially smallholder income
- Strengthen Nigeria's self-sufficiency in terms of rice production and consumption
- Improve resource use efficiency for rice production
- Reduce methane emissions attributed to rice production
- Improve supply chain efficiency and stability

4.2 Potential areas for loss reduction interventions

The emphasis of this pilot study was to develop a user-friendly and cost-effective loss measurement approach for the rice value chain linked to global standards and, tools and using it in practice to identify critical loss points. Throughout the course of the pilot, information obtained highlighted potential areas for loss reduction interventions. It must be noted that loss reduction trials were not conducted within this pilot. At this stage there is no specific indication with regard to investment costs or potential impact of the interventions suggested in this segment. Additional trials would be needed to understand the implementation costs and benefits of the suggested interventions.

4.2.1 Creating awareness with regard to the extent and impact of losses

The large difference observed between direct measurement of losses and farmer perception of losses highlights a need to continue making farmers more aware of losses occurring, emphasising on the impact such losses have in terms of their net farm profit and return on investment.
Having invested in quality seeds, agricultural inputs, labour costs and other inputs, farmers need to understand that losses in rice directly impact the profitability of their farm.

As the pilot findings show, approximately 1/3 of the produced rice is lost between the point of harvest and the procurement warehouse. In economic terms, rice farmers are potentially losing out on approximately USD 520 per hectare.

The measurement approach applied in this pilot study has the advantage of allowing farmers and farm labourers to visually see what is lost at each step of the production process and supply chain. Creating awareness regarding loss and the impact it generates needs to be complemented by loss reduction efforts geared at behavioural and management changes embodied by all actors within the value chain.

Olam could support pro-active farmers who are willing to actively invest to reduce losses by engaging them in field trails to measure, record and monitor the effectiveness of loss reducing (on-farm) practices, providing valuable field information and insights into the return on investment of loss reduction practices.

4.2.2 Capacity building for application of standardised good agricultural practices

When comparing losses in rice from one farm to another, high variability can be observed. More in-depth research is needed to unravel the relationship between farm management practices and on-farm losses. The pilot results indicate that some farms experience very low levels of loss which is promising in terms of potential best practices that could be replicated across other farms to reduce rice losses. Best practices at each critical loss point need to be identified and compared through field trials in order to understand their potential effectiveness.

Good Agricultural Practices (GAP) guidelines for rice production contain some elements that directly and indirectly relate to post-harvest loss prevention. Olam in coordination with GIZ has been training farmers on GAP for rice production. The majority of farmers interviewed for this study mentioned having received GAP training. From farm observation and surveys it became evident that farmers do not apply and have not adopted all recommended practices. **Continuous farmer training and capacity building on GAP with a particular focus on reducing post-harvest losses is essential**. One example of a promising low-cost practice is the systematic usage of tarpaulins during harvest and during transportation of rice from one field location to another. Training sessions are a good opportunity to promote the adoption of best practices.

From the conversations and interviews with farmers, it became evident that some farmers are trying out innovative practices to reduce losses at the critical loss points. Some farmers mentioned threshing in a bag or in a pit or even setting up low-cost structures in the field during harvest to protect harvested rice stalks from rainfall, excessive direct sunlight or other weather-related factors that potentially affect the quality and could lead to losses. It would be valuable to look into local innovations and their potential for loss reduction.

4.2.3 Areas for further exploration

Targeted investments considered could focus on the following interventions:

- ICT tools and services for real-time information and advice on climate forecasts
- Row planting and row harvesting
- Transplanting practices
- Improved usage of tarpaulins during harvest, transportation, heaping and piling
- Improved coordination for timely supply of adequate quantity and quality planting materials
- Training and on-farm follow-up on existing GAPs that could be adopted to reduce pre-harvest, harvest and post-harvest losses
- Further measurements, research and innovation on low-cost loss reduction practices and technologies, to compare effectiveness for example between bag threshing, local man-powered mechanical threshers and threshing in a pit
- Incentivising local innovation by organising regular loss reduction challenges and making available small farmer-oriented innovation funds
- Procurement, distribution and adoption of rice cultivars and seed varieties that are less prone to shattering and mature homogeneously

Table 4 provides a summarized overview of the main causes of loss, percentage estimate and potential loss reduction approaches that could be applied.

Table 4 *Summary of main causes of loss and loss reduction potential*

	Harvest	Heaping	Threshing	Winnowing	Packing	Transport to Olam
MAIN CAUSES OF LOSS	**- Rice falling off plant upon being harvested and moved** **- Immature rice harvested too early**	**- Rice falling off plant upon being handled and transported** **- Damage due to moisture** **- Damage due to rodents and insects**	**- Rice dispersed by threshing method** **- Rice remaining attached on plant after threshing**	**- Dispersed rice due to excessive winds and inadequate handling**	**- Spilling on the ground**	**- Spilling on the ground**
RICE LOSSES (in % of actual yield, average 4 regions)	**12%**	**4%**	**11%**	**8%**	**0%**	**0%**
Potential loss reduction tools and techniques	**- Sensitisation and GAP training including the development of a cropping calendar** **- Utilization of improved rice varieties that are less prone to shattering** **- Participatory field trials with farmers on loss reduction practices and technologies, for example:** **- Planting and harvesting techniques** **- ICT tools and services providing real-time information and advice on climate forecasts** **- Supporting farmers to obtain timely supply of planting material and other inputs**	**- Sensitisation and GAP training**	**- Sensitisation and GAP training** **- Field trials and observation on loss reduction practices and technologies** **- Testing existing farmer practices and innovations** **- Testing existing small scale mechanical threshing technologies**	**- Sensitisation and GAP training** **- Field trials on loss reducing practices and technologies**		

4.3 System approach to reduce food loss in agricultural supply chains

As the impact of food loss affects different stakeholders in diverse ways, effective strategies to reduce losses within the rice supply chain will require strong collaboration and engagement from stakeholders who share a common goal to reduce food loss. These strategies should consider the social, economic and environmental components related to food loss. The exercise of defining common objectives amongst different stakeholders will automatically generate increased collaboration between actors of the value chain providing agreements on how to approach and reduce food loss collectively as envisioned by the SDG target 12.3[14].

This pilot study has shed a light on the critical loss points within the value chain where rice losses occur. Nevertheless, this report does not advocate for interventions targeting loss reduction at one specific stage in the value chain. Sustainable, long-term strategies to reduce food loss require a package of interventions geared at approaching loss and inefficiencies through system-wide approaches.

Alongside stakeholder engagement, the promotion of an enabling environment, first-mile service improvements, sensitisation regarding food loss and food consumption patterns and promotion of circularity concepts to valorise by-products will be needed to achieve sectorial transformation.

Champions 12.3[15] and The Waste and Resources Action Program (WRAP) set up an approach to target, measure and act on food losses which has been successfully taken up by a series of countries and companies in the food and agriculture sector [16]. The target, measure, act approach stipulates that to effectively reduce food loss and waste, food businesses should:

1. **TARGET:** Set clear quantifiable and measurable loss reduction targets
2. **MEASURE:** Implement measurements to monitor food losses from throughout the supply chain
3. **ACT:** Act on loss by investing in loss reduction, establishing partnership to approach loss reduction collectively and by taking on a food system perspective approach to tackle losses from farm to fork.

Measurement methodologies should be applied throughout the supply chain to establish baselines and allow for regular monitoring and tracking of progress made from farm to fork. Surveys and farmer self-reporting is often considered as a cost effective approach for assessing losses. In smallholder supply chains, considering the variability in results between losses perceived by farmers and losses directly measured, any approach looking to assess losses should consider combining qualitative and quantitative data by complementing farmer self-assessments with direct measurements.

The evidence gathered from the pilot suggest that losses in the rice outgrowers value chain are predominantly located on farm in the initial harvesting and handling stages.

By implementing a systematic approach of targeting loss reduction at the critical loss points whilst measuring and monitoring loss reduction at these points, multiple stakeholders in the supply chain can benefit environmentally, economically and socially. Emphasis should be given to interventions, innovations, practices and technologies that are low costs and adapted to the local context as farmers are more likely to adopt these type loss reduction practices.

The measurement protocol used in this pilot study has proven to be user friendly for measuring losses at a farm level and can be adopted on a more consistent basis by trained Olam technical field staff.

[14] Target SDG 12.3: by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.

[15] https://champions123.org/

[16] https://www.oneplanetnetwork.org/initiative/food-waste-reduction-roadmap

Effective supply chain loss reduction requires the following preconditions:

- Engagement by all actors: losses are perceived differently, and the impact of losses is felt in distinct manners by different actors in the chain. For farmers, losses occurring on farm and quality rejects at the delivery point directly influence the profitability of their farms. For Olam, losses occurring on smallholder farms are not considered direct losses yet they affect procurement volumes and the availability of raw materials supplied to Olam's rice mill.
- A change of attitude towards loss measurements. Measurements and monitoring tools are often perceived as additional tasks yet the benefit of knowing how much is lost is the starting point to develop a resource-smart food system.
- Good record keeping and data management along the supply chain, starting at the individual farm level.

Building on the learnings of this particular food loss and waste measurement approach, similar approaches can be scaled to other rice producing countries where Olam is present and measurement approaches can be designed tailored to other commodities and specific supply chains of interest. The Guiding principles and steps in this process can be replicated and put to practice in different supply chains and geographies.

5 Discussion

5.1 Methodological learnings

5.1.1 Presenting the results

Losses were presented in percentages and not kilograms, since only three plots of $1m^2$ represent the total field per farmer. Showing the results in kilograms per square meter, or after upscaling into kilograms per hectare, will not visualise the amount of loss occurred in the different regions correctly, since the actual yields in kg per $1m^2$ for the individual farmers differ extremely. Explanations for this are:

- When the selected plots were not accurately measured and were slightly larger than $1m^2$, this can generate an error in yield per $1m^2$ and after upscaling to 1 hectare. However, this does not influence the percentage of losses.
- Although the plots were selected at random, the selected plots can have a higher productivity compared to other parts of the field. After upscaling, this results in a higher potential yield per hectare when compared to the literature. Selecting bigger sample plots, of for example $5m^2$, can improve the accuracy of this. Nevertheless, even then, selecting the plot and measuring exactly $5m^2$ are factors that influence yield after upscaling.

Both factors described above influence the amount of rice per $1m^2$ or per hectare in kilograms, but do not influence the percentage of losses, as they do not influence the ratios. This methodology focused on measuring losses and not on measuring the yield per hectare. Kabir et al. (2016) provide different methodologies to measure the production of rice and to estimate the area[17].

5.1.2 Assumption and challenges during data collection

Sample size

Initially, loss measurements were conducted with a sample of 80 farmers from four different regions in Nigeria. After initial review of the data it became apparent that the data collected from 20 farms in the Nasarawa region contained some errors, since the actual yield, and therefore the productivity of the plots (in kilograms) in this region was up to 4 times higher than other regions. Considering that the data for all individual farms in Nasarawa region produced these high results, it was defined as a recurring error. The analysis team determined this data as unreliable and it was decided to remove the data collected from these 20 farms from the data set as it was not possible to define the cause for this extreme data anomaly. Possible explanations for the high actual yield could be: weighing scale not calibrated, wrong data input, samples of more than $1m^2$, samples selected at parts of field with highest yield, or others.

In a limited number of cases, data analysis of the individual farms in the other 3 regions also portrayed extremely high actual yields. However, the number of these occurrences was relatively small; 5 farmers for Benue, 2 farmers in Plateau and 6 farmers in Taraba respectively. Potential factors that could explain these measurement results could not be backtracked. This data was included in the final results and analysis, since it was not tagged as outlier. It was not a recurring error and therefore it does not affect the final results.

Data checks were conducted after arrival of the completed data sheets. These quality controls focussed on correctly completed forms and the probability of the data with regards to the different activities. Additional data quality controls are required, and could be conducted by using automatic ICT systems, instead of manual checks. In order to improve and to prevent data errors, more data checks

[17] Kabir, M.S., Paul, D.N.R., Hossain, M.I. and Rahman, N.M.F. 2016. Estimating Area and Production of Rice under Different Crop-cut Methods in Bangladesh. Bangladesh Rice J. 20(1): 11-16.

are needed. For this pilot study, removing the data collected in the Nasarawa region did not influence the data and results in the other regions.

Harvesting
Losses occurring during harvesting could not be measured at all farms, due to what has been documented by the enumerators as water-logged fields. Water-logged fields are fields where the surface is muddy or wet. During the pilot, such conditions altered the rice moisture content and generated methodological concerns, as the moisture content fluctuated by more than 10%. Data on harvesting losses was collected from one sample in 28% of the selected farms. To overcome the actual yield data gap for the missing samples, a weighted average was used to estimate the losses during harvesting in these unmeasured samples. For follow-up measurements, this issue could be methodologically resolved by drying the samples first before weighing them, instead of correcting the weight post-measurement.
As the harvested rice is attached to the plant material at this stage, these were weighed together. During the data analysis this factor was corrected based on the ratio 'rice-to-plant–material' which was defined during the analysis of the data collected during the threshing activity for every sample separately.

Heaping
During the collection of data and the measurement of losses at this stage, the waiting time (drying time) that normally occurs in real field conditions was not taken into consideration. In reality, farmers often wait with heaping until the entire rice field is harvested. Additionally, farmers will often wait until the moisture content of the rice reaches a certain level to initiate their next activity, namely the threshing activities. As these waiting times were not considered in the measurements, it must be taken into account that in reality the losses occurring at this stage could be higher.
At the stage of heaping, rice loss was measured by considering the difference in weight before and after this activity. In this activity, the rice stalk, straw and other plant material was still attached to the rice grains and was therefore measured together. During this activity both rice and plant material could be lost. Therefore, the measured loss in weight is assumed to be a mixture of rice and plant material that was lost.

Threshing
An issue encountered with the data collected during the threshing activity was that the weighing was not always done properly. Sometimes the input weight that was registered was lower than the sum of the output weight, which is erroneous. This data was adjusted by modifying the weight of the plant material collected, so that the sum of the output weight equals the input weight. This particular approach for correction of data was chosen, considering that the values of successfully threshed rice cannot be adapted. Any adaptation regarding the successfully threshed rice would result in an adaption affecting the input data at the winnowing stage, which would in turn influence all the results moving onwards. The weight of the rice that was manually removed from the plant material cannot be adapted either, since this is a small weight. Therefore, the relative difference would be too big. Additionally, it was considered easier to measure a bowl with rice compared to plant material. Weighing plant material is complicated since it is impractical for the weighing scale and inaccuracies can easily occur. The adaption of the data can influence the overall results, since the ratio between plant material and rice is based on this activity and this specific ratio is used to calculate losses incurred in other activities such as for example harvesting and heaping and piling.
During this stage of the value chain, rice loss was measured as a combination of loss in weight and in rice that remained attached to the plant material. Methodologically, the assumption was made that the difference in weight was due to rice that was lost. Therefore, all loss measured was considered as loss in rice.

Winnowing
Under normal field conditions, farmers tend to wait before winnowing until the moisture content of the rice drops to around 11%, the level recommended by Olam. During data collection, this waiting time was not included in the measurement process. This could have influenced the results obtained during winnowing, considering that in reality, the samples of the threshed rice might have incurred further loss during the waiting time.

For the winnowing stage, the assumption was made that the difference in weight before and after performing this activity was entirely assigned to rice loss, since the weight of the foreign matter was considered negligible in comparison to the weight of lost rice.

Packing

Considering that, in the pilot measurements, the waiting period did not take place before winnowing, a waiting time was included between winnowing and packing in order to dry the rice to a moisture content of around 11%. Under normal conditions, most farmers will not store winnowed rice without packing it, but will leave the rice in the field to dry before winnowing. Additionally, in this pilot, the rice samples were taken home by the farmer or field team responsible for the measurements to store until moisture content reached acceptable levels.

Data registered during these steps revealed some inconsistencies. Overall, during the mentioned drying period, the moisture content decreased with a few percent, while the weight remained equal. This revealed that the registered data were incorrect. Therefore, no conclusions can be drawn based on measurements regarding losses during the waiting time. As was mentioned previously, the rice was stored in a protected environment during this period. This does not correspond with the real field conditions where rice is often stored in unprotected environment. This factor might have generated inconsistencies in the loss measurements. Additional measurements would be needed to draw conclusions with regard to the losses generated due to waiting and exposure to environmental conditions. Additional quality control checks along the data collection process can help to highlight these type of issues and modify the methodology whilst data collection is taking place.

The loss of rice during the packing activity was not measured on all farms. Data for the packing activity and the activities onwards was only collected for 49 out of the 60 farms. The farms with missing data and measurements were excluded from the analysis after winnowing.

Transport to on-farm storage and on-farm storage

In this pilot, farmers transported the bags to Olam immediately after packing. In real-life farmers normally store the bags of rice to sell at a later time, depending on the market price or by taking the time to gather a sufficient number of bags before hiring transportation. If measurements and data recording had included this on farm storage, this could potentially have resulted in higher losses, considering that rodent damage was mentioned by the farmers during the surveys as an important cause of losses at this stage.

Transport to Olam collection centres

Losses measured and recorded during transport activities can be lower compared to reality, considering that oversize loading, or damaged bags can cause additional losses.

Arrival and milling

The initial methodology took into account that a quality check of the samples is conducted at Olam collection centres, as these quality checks taken place when bags arrive at the collection centres. Results from these quality controls could have provided more insight in the percentage of rejection, but also in the percentage of immature rice, empty shells and foreign matter per bag. These measurements did not take place within the pilot. Generalized data on losses from the mill were provided by Olam.

Other learnings

Farms were visited during the peak harvest season in order for the data collection team to take direct field measurements. Managing day-to day procurement operations during the harvest season alongside coordinating the measurements for the pilot was challenging for Olam field coordinators as it is one of the busiest time of the season. In hindsight, we can conclude that the number of samples was too large for the short harvest time-frame and with the manpower available on-site. As a result, some of the supply chain activity stages that were initially included in the protocol were not measured such as: harvest loss for the selected farms that were waterlogged, on-farm storage loss, the waiting and drying time between stages, and the samples that were not weighted before packing. The incompleteness of the data set is mainly due to time constraints rather than the methodology. Therefore, taking the pilot learnings into consideration, it is recommended that, for follow-up measurements applying the similar protocol, field staff are further trained on the methodology to enhance their knowledge and measurement skills. In addition, either a longer period of time should be allocated for data collection, or more manpower should be trained to take the measurements, or the sample size should be reduced. By allowing more time, it becomes possible to visit the farms several times during the measurement period and include the drying stages and on-farm storage activity, which will provide deeper insights.

For the purpose of the pilot, industrial weighing scales were used to measure the harvested quantities of rice, including the plant material. For follow-up measurements, more precise and granular weighing scales could be used to improve the accuracy of the measurements. Alternatively, the weight of each sample could be increased by modifying the sample area that is measured, adjusting from plots of $1m^2$ to plots of $5m^2$. The change in sample size might increase the accuracy of the measurements, yet the cost of measurement might increase too since more time per sample will be needed to go through all the pilot steps.

Conclusion
Overall, more attention should be paid to perform regular quality checks and discuss possible methodological adjustment with the field team during the process of data collection.
During the data collection stage of this pilot study, many challenges were faced due to time constraints and a limited number of people involved in data collection.

This pilot was a proof of concept for a supply chain food loss and waste measurement approach. The methodology we followed will be adapted based on the following learnings:
- Sample size should be reduced or samples should be taken from larger sample plots at each location
- Due to the intensity of the data collection process, one team of enumerators should visit a maximum of 3 farms per day
- Olam field staff were involved throughout the pilot in the data collection process and are now able to conduct follow-up measurements. For new recruits, in-depth training on data collection methods will be required
- Due to the short harvest period and the limited time window for loss measurements, the process requires a sufficient number of enumerators available for the number of farms assessed with data quality checks performed on a daily basis
- Develop a proposal for an online data collection tool that is linked to the Cool Farm Tool, that can reduce the potential for transcript errors and can allow for continuous data control and monitoring of data collection.

5.2 Literature comparison of the measured losses

Based on available research and literature, on-farm losses in the rice value chains in low and middle income countries range between 10% and 40%.[18]
In Nigeria, the German Federal Ministry for Economic Cooperation and Development (2014) reported rice loss at farm level of 11.39%, from the point of harvest to the transportation of dry rice to the next actor in the chain. In the mentioned study, a total of 211 farms were selected from Niger and Kogi state in Nigeria, and the survey data was collected on field visits, using local measurement units like the number of buckets and "mudu". The weight of these equivalents were then validated by direct measurements. The critical loss point observed by GIZ was during harvest was due to damaged rice panicles with 4.35% loss and during threshing and winnowing of rice with 4.98% loss.[19]
In a study conducted in the Ashanti region of Ghana, Appiah et al. (2011) concluded that sickle-harvesting resulted in a 2.93% loss and threshing in a 6.14% loss. The data was collected by taking three direct measurements, complemented by thirty semi-structured questionnaires. Farmers faced

[18] Saba and Ibrahim, 2018. Postharvest Loss in Rice: Causes, Stages, Estimates and Policy Implications. Review Article. Agricultural Research & Technology Open Access Journal. ISSN:2471-6774.

[19] The Federal Ministry for Economic Cooperation and Development, 2014. Post-Harvest Losses of Rice in Nigeria and their Ecological Footprint. Published by GIZ, GFP, CARI and SNRD. https://www.giz.de/fachexpertise/downloads/giz2014-en-post-harvest-losses-of-rice-in-nigeria-and-their-ecological-footprint.pdf

the highest on-farm losses during harvesting, threshing and drying with losses ranging between 4.6% and 17.88%, and excluding losses occurring during storage, transportation, winnowing and handling[20].

In all the studies discussed above, loss estimates are mainly based on surveys and questionnaires rather than direct measurements. Although methodologies cannot be compared, all studies converge towards the same critical loss points **concluding that the highest losses are found during harvest and threshing activities**. Nevertheless, stark differences are found in the amounts of loss when comparing survey responses and farmer self-reporting from these studies with the direct measurements of the pilot study. This is attributed to farmers underestimation of losses.

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