Measuring food losses and their ecological footprint – a case study using rice value chains in Nigeria

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Abstract

A high amount of food produced for human consumption is lost or wasted globally. However, to evaluate and quantify food losses is difficult. GIZ therefore has commissioned some studies on various products with the aim to quantify losses during harvest and post-harvest stages and to develop recommendations for reducing those losses. At the same time, food losses have their "history" and represent a waste of resources used in production and processing that have been "consumed" before the final product, parboiled milled rice. Life cycle assessment (LCA) was used as standardized scientific method for systematic environmental impact analysis. This "twin approach" (definition of food losses and of the environmental impact) was applied using rice value chains in Nigeria as an example. Land occupation, water stress footprint and global warming potential were assessed and results show a reduction of food losses will lead to strong environmental benefits. The study concerns two rice value chains which are predominant in two states of Nigeria: the traditional value chain of small-scale farmers producing rice in the form of mainly rain-fed agriculture on small fields followed by parboiling and milling, and the industrial value chain of commercial farms and enterprises with integrated processing. The level of yield as well as quantity and quality of the processed products remain well below the potential, and the high demand for rice in Nigeria is impacted. Thus, reducing post-harvest losses in the rice value chains is a key factor to improve food security. Understanding of the negative environmental impact can be created. Furthermore, conclusions can be drawn that the avoidance of food losses can particularly contribute to greenhouse gas mitigation. The lack of good processing, storage and transport facilities is a contributing factor, as well as diseases and pests, to the losses in the post-harvest sector. Conclusions for the reduction of losses for the promotion of food security are discussed - including strengthening cooperation with the Competitive African Rice Initiative (CARI).

Keywords: rice, post-harvest, food losses, Nigeria, ecological footprint

1. Introduction

1.1. Rice production in Nigeria, West-Africa

Even with large food imports, the Food and Agriculture Organization (FAO, 2012) indicated that about 9.4 million Nigerians were undernourished, which represented about 6% of the population (NBS, 2012). Given the level of poverty, food insecurity and undernourishment in Nigeria, along with food losses and waste, which occur along the entire food value chain, are unacceptable. Against this background, little attention has been paid to the potential of increasing food availability through a reduction in food losses and waste in the value chain. In fact, there are few studies on post-harvest losses in the food value chain in Nigeria.

Rice is a major staple food in Nigeria. Due to its large population, Nigeria is also the region's largest consumer of rice in absolute terms. The country's estimated annual demand for milled rice is 5.2 million tonnes, while the average national production is 3.3 million tonnes. The supply and demand gap of 1.9 million tonnes can only be bridged by importing rice. Over the years Nigeria has attempted to increase local rice production with a view to reducing imports. The goal of the current Federal Government's rice transformation agenda is self-sufficiency in rice production and complete cessation of rice imports[1]. With regard to the prevalent natural resources, there is no reason why Nigeria should be a net importer of large quantities of food.

Rice is cultivated throughout Nigeria, from the mangrove swamps of the Niger Delta to arid regions near Lake Chad. However, there are three federal states that are most important for rice cultivation: Niger, Kogi and Nasarwa. This study has selected Kogi and Niger as target areas. The dominant rice systems in these areas are irrigated lowlands, rain fed lowlands and rain fed uplands (Longtau, 2013). These systems are defined as follows (*ibid.*):

- Lowland: Rain fed or irrigated rice in aquatic conditions or medium ground water table. Water covers the soil completely at some stage during the cropping season. These are called shallow swamps or fadama (irrigable land) (Figure 1).
- Upland: Rain fed rice grown on free- draining fertile soils. This is also called dry uplands.

Figure 1 Rain fed lowland rice cultivation system (Niger state; source: PE/GIZ).

This study focuses on lowland rice cultivation (mainly rainfed, in some places irrigated), which makes up 55 per cent of rice production in Nigeria (*ibid.*), and is even more prominent in the two target areas. As more fertiliser is used in Niger than in Kogi, one of the main differences in rice production between the two states lies in the yields. Irrigation is also more widespread in Niger.

1.2. Study objectives

Considering the high demand for rice in Nigeria, a study designed to quantify losses and waste along its value chains has the potential to generate information that can be used to design interventions that may be able to counter these problems and hence increase food availability. Food losses do not only reduce the food available for human consumption. The associated externalities negatively affect society in the form of the costs of waste management and the production of greenhouse gases. Food loss is estimated to be equivalent to 6 to 10 percent of human-generated greenhouse gas emissions (Vermeulen et al., 2012).

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been studying impact and possible prevention of food losses for some time. Preceding this study, GIZ conducted an investigation of food losses and their environmental impact along the value chain of cassava and maize in Nigeria (Oguntade, 2012; Thylmann et al., 2013). The study clearly indicated that food losses in the two value chains have a significant impact on the environment, emitting up to 2.3 million tonnes of CO_2 eq. into the atmosphere.

This study follows the approach of its precursors. The aim is to improve data availability concerning food losses in rice value chains in Nigeria and to identify options for the public as well as the private sector to engage in rice post-harvest losses reduction programmes. The study comprises of two parts: Part 1 describes and analyses the rice value chain and quantifies the losses. Part 2 builds on the insights of part 1 and provides an estimation of the impacts of food losses on natural resources like land and water as well as with regard to climate change (greenhouse gases).

The intended audience of this study are members of GIZ and their consultants, experts in the agricultural sector (especially those dealing with post-harvest losses), policy-makers in Nigeria, LCA practitioners, and the interested public.

2. Materials and Methods

2.1. Definition of food losses

According to FAO (Gustavsson et al., 2011), the term "food losses" refers to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses occurring at the end of the food chain (retail and final consumption) are called "food waste", which relates to retailers' and consumers' behaviour. Food waste is thus not covered in this study. Five system boundaries were distinguished in the food supply chains of vegetable and animal commodities by FAO:

1) Agricultural production: losses due to mechanical damage and/or spillage during harvest operation, crops sorted out after harvest, etc.

2) Post-harvest handling and storage: including losses due to spillage and degradation during handling, storage and transportation between farm and distribution.

3) Processing: including losses due to spillage and degradation during industrial or domestic processing, e.g. juice production, canning and bread baking. Losses may occur when crops are sorted out if not suitable to process or during washing, peeling, slicing and boiling or during process interruptions and accidental spillage.

4) Distribution: including losses and waste in the market system, at e.g. wholesale markets, supermarkets, retailers and wet markets.

5) Consumption: including losses and waste during consumption at the household level.

In this study, only food losses occurring up to the end of processing and retailing are considered (cradle-to-shelf approach - phases 1 to 4).

2.2. Data collection on food losses

Different participants in the value chain in Niger and Kogi State (farmers, marketers and

[1]Local Government Areas are administrative units similar to counties.

millers/processors) were interviewed by trained enumerators. In Niger and Kogi States, two Local Governments Areas (LGAs)[1] which are high producers of rice were selected. Thus four LGAs were selected for the study. The sample of respondents was selected at random from a list of rice farmers and other actors along the value chain. Altogether, 211 farmers, 32 marketers (wholesalers and retailers) and 32 millers were interviewed.

The cultivation of rice is dominated by smallholder farmers and their household members while rice paddy processing is undertaken by two separate actors using two different technologies. On the one hand these are the cottage entrepreneurs who produce basic milled rice and on the other the industrial processors who operate integrated mills and produce value-added rice. The study therefore includes data from one modern rice mill in Niger state.

The pre-field data collection visits to Kogi and Niger States identified the need to use direct measurements to complement questionnaire administration in order to calibrate the various volume measures that are being used along the rice value chain. Also, the measurements in use (bucket, oyomoyo, mudu and adamu) are not standardised across all locations. In Kogi State, bucket, oyomoyo and adamu are used while in Niger State, mudu is the common unit of measurement. Therefore, as part of the study, direct measurements were undertaken to convert the traditional measurements into weight equivalents.

2.3. Environmental footprint

The product system under study covers the process steps from cultivation to distribution: cultivation, post-harvest losses, processing to final product, and transport to point of retail (cradle-to-shelf approach). The final product considered is parboiled milled rice. In order to assess the environmental impacts of food losses in rice production in Nigeria, a Life Cycle Assessment (LCA)[2] in accordance with ISO 14040/44 was carried out by PE INTERNATIONAL AG on behalf of GIZ (Thylmann et al., 2013). Life Cycle Assessment is a standardised scientific method for the systematic analysis of flows (e.g. mass and energy) associated with the life cycle of a specific product, technology, service or manufacturing process system in order to assess environmental impacts (Figure 2). According to these standards an LCA study consists of four phases (ISO, 2006):

1) Definition of goal and scope (framework and objective of the study);
2) Life cycle inventory (input/output analysis of mass and energy flows);
3) Life cycle impact assessment (evaluation of environmental relevance, e.g. GWP); and
4) Interpretation (e.g. optimisation potential).

The study includes the following inventory flows and environmental categories[1]:

- Climate change (global warming potential, GWP);
- water (water stress footprint);
- land occupation.

An overview of the impact categories is given in Table 1.

[2]The LCA model is created using the GaBi 6 Software system for life cycle engineering, developed by PE INTERNATIONAL AG (2013). The GaBi database provides the life cycle inventory data for background systems such as fuels and energy, fertilizer and pesticide production, transport emissions etc. Primary and secondary data collected were added to GaBi 6 background data.

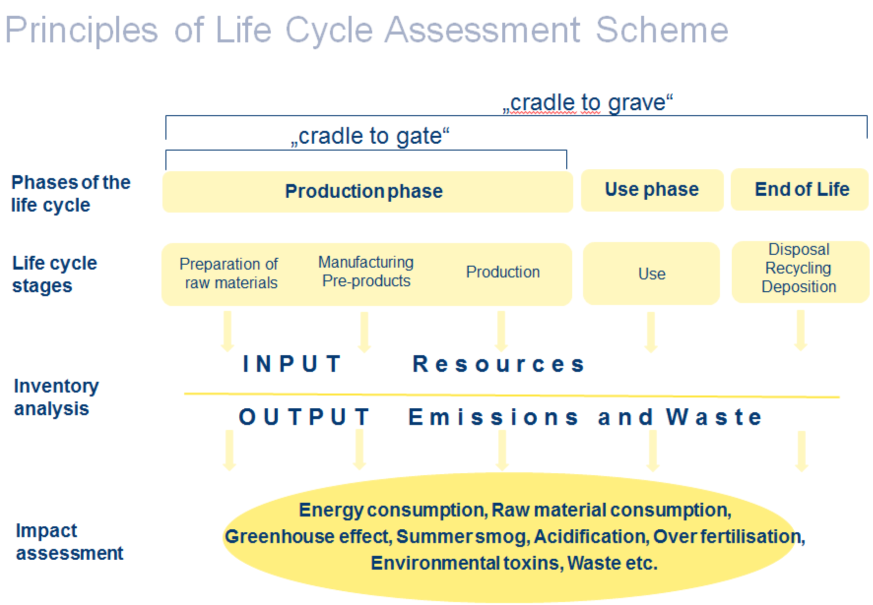

Figure 2 Principles of the Life Cycle Assessment (LCA) Scheme.

Table 1 Life cycle impact assessment categories and indicators.

LCIA categories and indicators used in assessment of environmental footprint of PHL rice and rice production in Nigeria

Category Indicator	**Impact category**	**Description**	**Unit**	**Reference**
Climate Change	Global Warming Potential* (GWP)	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, magnifying the natural greenhouse effect. This impact category is also often referred to as “Carbon Footprint”, but as global warming potential is a more precise description, the term GWP is used in this study.	kg CO_2 equivalent	IPCC (2006), 100 year GWP is used
Water	Water stress footprint	The water stress footprint of a system is a set of different calculations and should be used as an umbrella term rather than to communicate a single number. So far, water footprinting focuses on the water lost to the watershed, i. e. water consumption. Water consumption is considered to have a direct impact on the environment (e. g. freshwater depletion and impacts on biodiversity). In the assessment of water consumption it is crucial where it takes place. This is addressed by applying the water stress index (WSI).	m^3	
Land use (occupation)		As a sub-group of *land use* (functional dimension of land and area that is used for urban, agricultural, forestry and other purposes) *land occupation* can be defined as the maintenance of an area in a particular state over a particular period of time.	hectare	

* The terminology “potential” is used by ISO to clearly indicate that LCA shows possible impacts in the future. For example for climate change the Global Warming Potential represents the potential impact of greenhouse gas (GHG) emissions.

3. Results and Discussion

3.1. Quantitative and economic losses

The data on losses in the value chain shown in Figure 3 describe the damages and losses reported at each stage of the chain (farmers, processors, marketers). The percentages are based on different produce quantities and are therefore not part of an overall percentage. However, they do expose significant hotspots and challenges in terms of post-harvest losses. Harvesting / threshing and parboiling are the main hotspots followed by losses occurring during milling including transport. The retail level also contributes to losses.

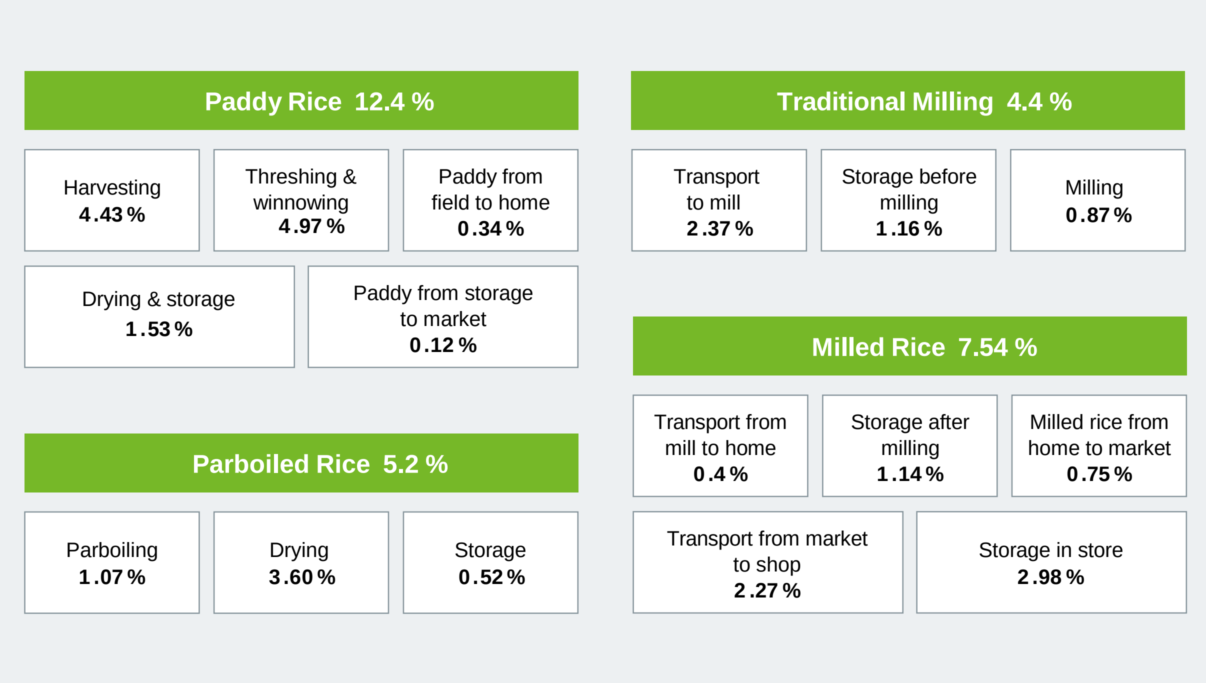

Figure 3 Synopsis of reported damage and loss occurring within different market channels.

Post-harvest losses in food value chains include both measurable quantitative and economic losses over the course of transforming food from one form to another; right from the farm gate up to the consumers' table. The quantitative loss implies a reduction of the physical substance of the product that is reflected in weight loss. The weight losses considered in this study include loss of weight due to product loss and loss of by-products due to the processing technology's inability to separately capture rice bran and husk. To measure the economic losses, the two quality standards of rice that were covered in this study, basic milled and value-added rice, were compared. The difference in the market values of the two types of rice formed the basis for assessing the qualitative losses.

At the level of milling, the input-output information for both the traditional and the integrated rice mill is provided per tonne of rice paddy (Table 2). The traditional rice mills have basic milled rice as their single output with an efficiency of 71 per cent while the integrated mills produce broken rice grains (16 per cent of input), value-added rice (55.1 per cent), rice bran (8.9 per cent) and rice husk (20 per cent). The output of the traditional system seems to be higher, yet it produces a mixture of whole grain and broken rice with an overall lower quality compared to the value-added rice of the integrated mill. The residue of the traditional mill is a mixture of broken grains, bran and husk. Most of the farmers claimed they simply throw it away. In the integrated rice milling system on the other hand broken grain and rice bran are by-products, which have economic value and are sold. Rice husk as a sole residue is used instead of fuel oil to fire the mill's boiler. The integrated mill consulted in this study placed a value of Nigeria Naira (NGN) 180 per kg on the husk. The only waste to be disposed of is therefore the rice husk ash.

Table 2 Outputs per tonne of paddy in traditional and integrated rice mills.

Type of Rice Mill	Product	Kg	Output per Input in %	Price (NGN/kg)	Value (NGN)
Integrated	Rice bran	89	8.9	180.00	16,020.00
	Rice husk	200	20.0	180.00	36,000.00
	Broken rice	160	16.0	113.00	18,080.00
	Value-added rice	551	55.1	170.00	93,670.00
	Total	1000	100.0		163,770.00
Traditional	Basic milled rice	710	71.0	113.42	80,528.20
	Residue	290	29.0	Nil	Nil
	Total	1,000	100.0		80,528.20

The financial losses were estimated in this study by comparing the two rice quality standards, basic milled and value-added rice. The price of the value-added rice was NGN 170 per kg while the basic milled rice was sold at the rate of NGN 113.42 per kg which is about the same price the integrated mill received for its broken grains.

Furthermore, traditional rice millers are losing rice bran because of using inappropriate technology. The rice bran is a raw material for the production of livestock feed. The loss of value amounted to NGN 16,020 for the 89 kg of rice bran per tonnes of paddy. In addition, the use of rice husk to fire the boiler and parboil rice paddy in the integrated mill saves wood fuel which is the main source of energy for parboiling rice for the traditional mills.

The value of the outputs per tonne of paddy from the traditional and the integrated mill was NGN 80,528.20 and NGN 163,770.00, respectively. The difference of NGN 83,241.80 paints a clear picture regarding the differences in the financial performance of the two technologies.

3.2. Environmental impact of the final product

In order to understand the environmental impacts of post-harvest losses along the Nigerian rice value chain it is important to know the environmental impacts of 1 tonne of the final product (parboiled white rice) and the way in which these impacts are spread across the various lifecycle phases.

The global warming potential (GWP) of 1 tonne of rice is 1.26 tonnes of CO_2 eq. in Kogi and 1.2 tonnes of CO_2 eq. in Niger per tonne of final product (parboiled milled rice) in the traditional value chain. The global warming potential is dominated by the methane emissions from the paddy field. The production of fertiliser used on the field and other field emissions (mainly laughing gas) also contribute significantly. But the second largest emissions occur during parboiling. Due to incomplete combustion a fraction of the carbon bound in the fuel wood is released as methane, which is a 25 times more potent greenhouse gas than carbon (note that the CO_2 emissions during combustion are not accounted for, because the CO_2 was taken up in the biomass before).

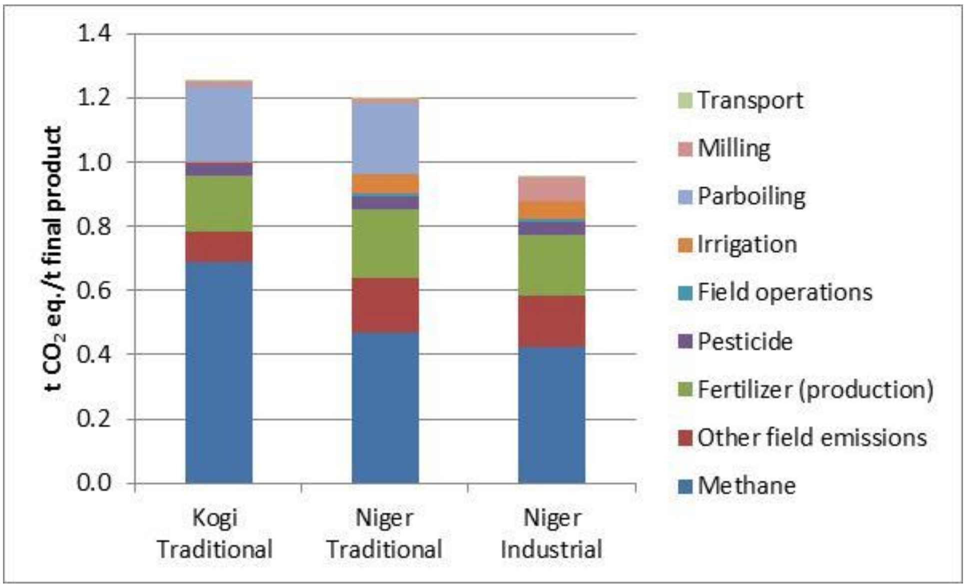

Figure 4 Contribution of various life cycle phases to the GWP of 1 tonne of rice.

The differences between the Kogi and Niger value chains (Figure 4) can be explained to a large extent by differences in rice yields. Methane emissions occur on an area basis and the higher the yield, the lower the emissions per kg of final product. As more fertiliser is used in Niger, the non-methane emissions ('other field emissions') in Niger are higher than in Kogi due to the larger availability of nitrogen. Also the emissions from irrigation (diesel consumption and combustion in irrigation pumps) are higher in Niger as irrigation is wider spread in this region. Still, in total the global warming potential of 1 tonne of parboiled white rice is slightly lower in Niger than in Kogi.

The industrial value chain shows a 20 per cent lower global warming potential than the traditional value chain (0.96 tonnes of CO_2 eq. / tonne of final product). This can be explained by lower losses along the value chain, i. e. less paddy is needed to produce 1 tonne of final product, thus less field emissions are caused per tonne of final product. Further, in the industrial mill controlled combustion of biomass leads to much lower greenhouse gas emissions. In Figure 4 all emissions occurring during the industrial processing of rice are summarised in the category 'milling'. Additionally, as in the industrial milling process valuable by-products are produced (bran and broken grains), a fraction of the environmental burden of the upstream process can be attributed to these by-products. It is also worth mentioning that energy use in processing as well as transportation only play a minor role in both value chains.

The next figure (Figure 5) shows the contribution of different phases to total fresh water use. Fresh water use includes surface-, ground- and rain water (green water). Water use also includes water used for the provision of energy, where water used for cooling and the provision of hydro energy plays an important role.

The total freshwater use to produce 1 tonne of rice is 3,477 m^3 in Kogi, 3,297 m^3 in Niger (traditional value chain) and 3,176 m^3 in the industrial value chain. Water use is dominated by the use of natural precipitation. Upstream and downstream processes (provision of energy, processing) contribute only little to water use. Due to the electricity used in the industrial parboiling process, the upstream water use (cooling water in generation of electricity) for industrially processed rice is a little higher than in the traditional value chain.

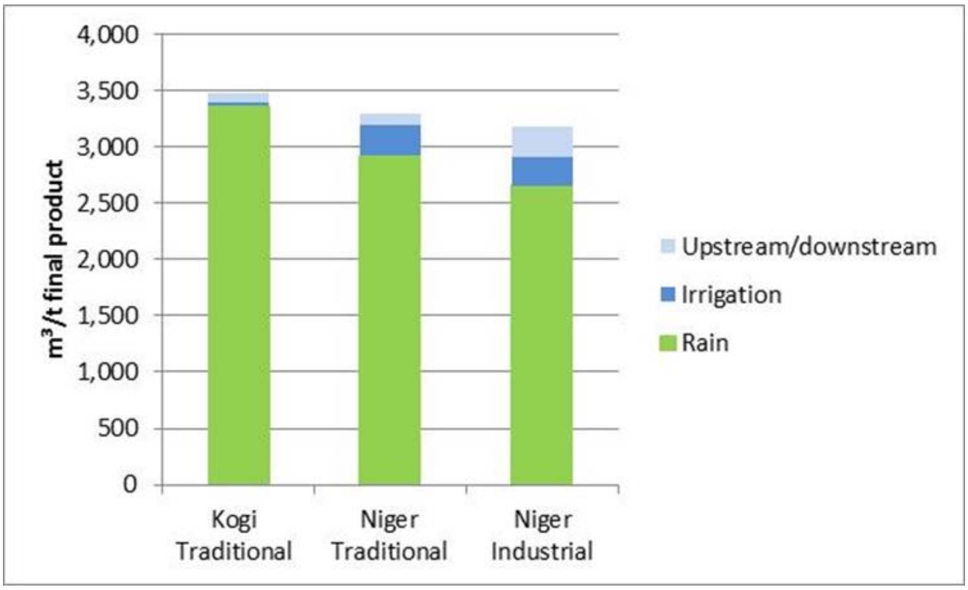

Figure 5 Contribution of different life cycle phases to total freshwater use [m³] of 1 tonne of rice in three rice cultivation systems.

Following the rationale of Bayart et al. (2010) and the "water use in LCA" - working group of the UNEP-Setac, water footprinting in a LCA context focuses on the water lost to the watershed, i. e. water consumption. Water consumption is considered to have a direct impact on the environment (e. g. freshwater depletion and impacts on biodiversity). When assessing water consumption it is crucial where the consumption takes place. In water abundant areas the effects of water consumption will have a very low impact, while in dry areas the effects will be large. This difference is addressed by applying the water stress index (WSI) developed by Pfister at al. (2009). The water stress (scarcity) index is used to weight water consumption according to regional availability. The resulting value is called "water stress footprint" (Figure 6). Rain water is not considered in that category.

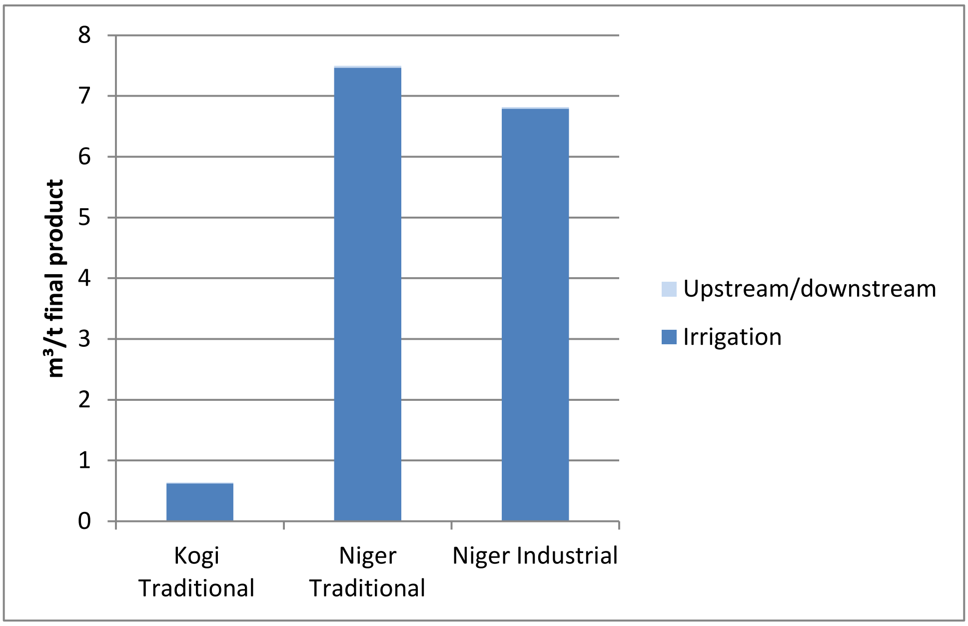

Figure 6 Contribution of different life cycle phases to water stress footprint [m³] of 1 tonne of rice.

It can be seen that only a minor fraction of the total freshwater use is relevant for environmental depletion in a narrow sense, i.e. is contributing to water stress. As rain water is not considered in that impact category, irrigation is the dominant contributor here. As only a minor fraction of farmers in Kogi use irrigation (or have access to irrigation) the water stress footprint of rice production in Kogi is smaller than in Niger. The water stress index (WSI) is 0.0103 in Kogi and 0.016 in Niger. This means that both areas have a similar water availability and are not classified as water stressed (WSI > 0.2). For details on how the WSI is calculated and interpreted, please refer to Pfister et al. (2009). The next impact category to be investigated is land occupation (Figure 7).

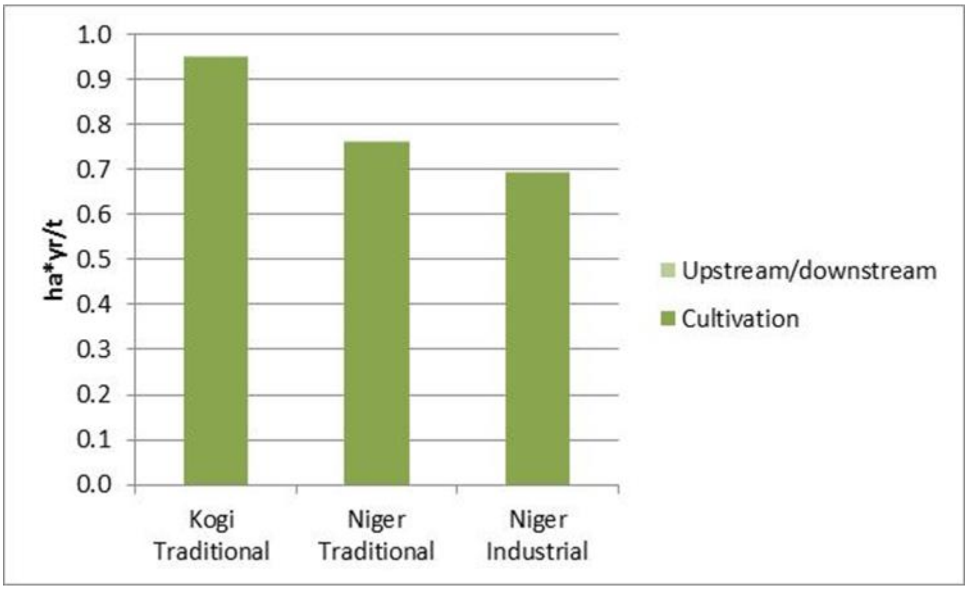

Figure 7 Contribution of different rice cultivation systems to land use (occupation): ha*yr/1 tonne of rice final product.

Occupation of land refers to the maintenance of an area in a particular state over a particular time period. Obviously this impact will be dominated by the agricultural phase, i.e. area required to cultivate the crop. Only a negligible fraction (< 0.5 per cent) of the total land occupation is associated with upstream processes. The difference between the value chain in Kogi and Niger can again be explained by the differences in yield, as the higher the yield, the smaller the area required to produce 1 tonne of final product. The differences between the industrial and the traditional value chain in Niger can be explained by lower losses and because part of the land use is attributed to the by-products generated in the industrial value chain.

3.3. Environmental impact of total losses

To calculate the environmental impact of all losses along the value chain, the loss quantities are multiplied with the impact of the product under study at the respective processing stage. Afterwards all impacts are summed up to result in the total impact in a given impact category.

The quantities lost along the rice value chain, the impact of the product per tonne and the total impact of the losses at the respective stage care listed in Table 3. The post-harvest losses (PHL) and the related impacts are calculated for Nigeria as a whole, i.e. the average of the traditional value chain in Kogi and Niger is considered to be representative for the total national rice production. The industrial value chain has not been considered as no data were available on the market share of industrially processed rice in Nigeria. However, it can be assumed to be low as even the few existing industrial mills do not run at full capacity (Brüning et al., 2013**Error! Reference source not found.**). Additionally, the data for the industrial value chain in this study are based on a specific mill that had just started operation recently, so it can also be questioned whether this mill adequately represents industrial rice processing in Nigeria.

Table 3 Summary of environmental impact of rice PHL in Nigeria (production quantities of FAO (2014), only traditional value chain considered).

Processing step	**Produc-tion**	**Loss total**	**Loss**	**GWP**	**Water stress**	**Land occu-pation**	**GWP of total loss**	**Water stress footprint of total loss**	**Land occu-pation of total loss**
	million tonnes	million tonnes	%	tonnes CO_2 eq./tonne	m³/tonne	ha/tonne	million tonnes of CO_2 eq.	million m³	million ha/year
Paddy	4.8	0.58	12	0.6	2.2	0.5	0.4	1.3	0.3
Parboiled rice	4.3	0.27	6	0.8	2.3	0.6	0.2	0.6	0.2
Milled rice	2.8	0.06	2	1.2	3.5	0.9	0.1	0.2	0.1

The environmental burden per tonne of final product grows larger with every new loss at each successive stage in the process because all impacts caused earlier in the process are added to the new stage's impact. Each loss-stage is successively associated with higher environmental burden, because impacts caused upstream in the value chain are all allocated to the product at the respective stage.

Looking at the GWP of the complete rice value chain, it can be seen that the food losses investigated in this study do indeed have a large environmental footprint. The GHG emissions into the atmosphere from losses in the rice value chain amount to around 0.65 million tonnes of CO_2 eq. per year. The losses along the rice value chain account for a water stress footprint of 2.1 million m³ (the term refers to water that is lost for further uses). Nevertheless, as rice cultivation is still mainly rainfed in the regions under investigation, and because these regions are characterised by a low WSI (Pfister et al., 2009), water does not appear as an environmental hotspot in the rice value chain in Nigeria. In Nigeria around 2.7 million hectares are planted with rice in 2012 (FAOSTAT, 2014). The land required to grow the rice lost along the value chain amounts to 0.5 million ha. That means that land occupation through losses accounts for 19 per cent of cultivated area.

3.4. Future Best Scenario – potential reduction of environmental impacts after the CARI intervention

The Competitive African Rice Initiative addresses important aspects for improving the rice value chain, which in Nigeria is largely inefficient and only developing in few selected areas. In order to assist the rice farmers, the programme is supporting both a sustainable increase in the intensity of small-scale rice cultivation and the development of inclusive business models. Such models improve access to equipment and services such as:

- ✓ Improved technology, seeds and other inputs for cultivation, threshing and harvesting;
- ✓ Appropriate parboiling and milling technology, also in order to achieve a product of high quality;
- ✓ Promotion of the role of women within the value chain;
- ✓ Capacity building for farmers and millers.

This creates a more stable market for produce and as consequence the reduction of food losses. In order to define the potential effect of the CARI initiative on the environmental impacts of rice as assessed in this study so far, a “future best” scenario was laid out. The results calculated under this scenario were compared with the Niger industrial baseline scenario. The following assumptions were made:

- ➢ Yield increase from currently 1.9 tonnes/ha (Kogi) and 2.3 tonnes/ha in Niger to 4.5 tonnes/ha (CARI goal: 3-6 tonnes/ha);
- ➢ Optimised fertilisation (according to the removal of nutrients with the harvest);
- ➢ Improved access to pesticides (amount of pesticides applied doubled);
- ➢ Improved access to irrigation: farmers that use irrigation assumed to be 50 per cent (currently 3 per cent in Kogi and 24 per cent in Niger);
- ➢ Losses during harvest, threshing and winnowing halved (due to training and improved access to technology);
- ➢ Industrial value chain considered (CARI goal: use industrial mills at full capacity).

Figure 8 compares the contribution of different life cycle phases to the global warming potential of 1 tonne of milled rice from the current industrial value chain (baseline scenario) and under the “future best industrial” scenario.

It can be seen that an increase in productivity can potentially lead to reduced greenhouse gas emissions per tonne of final product (-24 per cent). If the yield is increased, field emissions are distributed over a larger quantity of rice leaving the field, hence reducing the emissions per kg (though increased fertiliser use will lead to higher absolute emissions on a per ha basis). The increase of agricultural inputs and higher energy demands for irrigation do not equal out this effect. Thus, from a global warming perspective, an increase in productivity can potentially lead to environmental benefits. The intended productivity increase of the CARI initiative could potentially lead to a reduction in greenhouse gas emissions of 1.4 million tonnes CO_2 eq., assuming a total production of milled rice of 2.78 million tonnes, all processed traditionally, compared to the same amount produced completely under the “future best” scenario. These savings would represent a 1.8 per cent reduction of all GHG emissions in Nigeria.

However, it has to be stated that other important environmental aspects, such as eutrophication or the release of toxins into the environment as well as social aspects of the intended productivity increase, were not assessed in this study. Such an assessment would be required before making claims about the positive impact of the planned initiative.

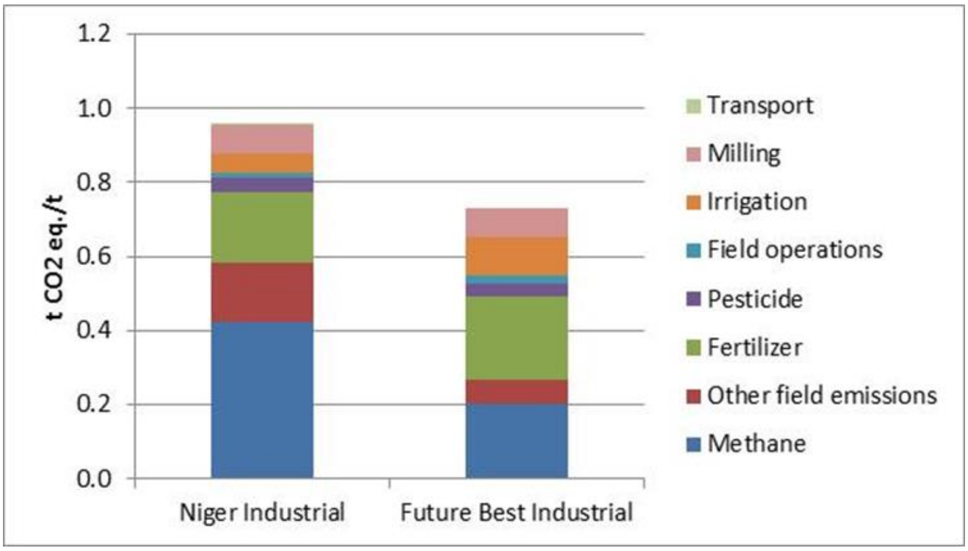

Figure 8 Contribution of various life cycle phases to the global warming potential (GWP, t CO_2 eq.) of 1 tonne of rice, comparison of two scenarios.

3.5. The reduction potential of using improved stoves for parboiling

Emissions from parboiling contribute significantly to the global warming potential of rice in the traditional value chain. Parboiling in this case was assumed to be done over open fires. A variety of projects exist that promote stoves which burn biomass more efficiently and protect human health at the same time. A very promising approach is micro-gasification. Gasifiers currently provide the cleanest option for using biomass for cooking (Roth, Volkmer, 2014). Gasifiers make their own gas from dry solid biomass and allow users to cook with it. At the same time bio-char is created, a valuable material that can be used for various purposes (*ibid.*). Different biomass sources could be used in gasifiers. The possibility of using rice husk as fuel is of particular interest for the rice value chain. Hence, the stoves could improve the parboiling process with regard to the environment (e.g. through reduced emissions and less pressure on natural resources such as timber for fuel), economically (e.g. saved spending on fuel wood) and socially (e.g. improved health through avoided toxic emissions). The emission with the largest effect on global warming from open combustion is methane. Even if only half of the methane emissions were avoided (conservative estimate), the global warming potential of the traditional rice value chain would still be reduced by 9 per cent. This is a clear indication that using improved stoves will reduce the environmental impact of the traditional rice value chain in Nigeria.

4. Conclusions

The role of emissions of rice cultivation should be put into a global perspective. Due to the methane emission occurring while the rice fields are flooded, rice in general has a higher global warming potential than other staple crops like maize, wheat or potatoes (on a kg or kcal basis). World wide rice cultivation alone contributes to 1.5 per cent of global greenhouse gas emissions, which is about the same as that of all air transportation. This is already a clear indication that combatting food losses in rice value chains can have a large beneficial impact with regard to global warming. When considering that rice is the staple crop contributing most towards human nutrition the importance of addressing food losses in the rice value chain becomes even clearer.

The cultivation phase is the main contributor to global warming potential along the rice value chain. 80 per cent of all emissions caused until the final product is made occur on the field (even 91 per cent for the industrial value chain). This means that even losses occurring at an early stage in the value chain have a large environmental impact.

Reducing food losses is an important measure in order to lessen the environmental impact along the rice value chain in Nigeria, but unlike other measures it is also vital for an improved food security in Nigeria.

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References

Akagi, S.K., Yokelson, R.J., Wiedinmyer, C., Alvarado, M.J., Reid, J.S., Karl, T., Crounse, J.D., Wennberg, P.O., 2011. Emission factors for open and domestic biomass burning for use in atmospheric models. Atmos. Chem. Phys., 11, pp. 4039–4072. Retrieved from URL: www.atmos-chem-phys.net/11/4039/2011/doi:10.5194/acp-11-4039-2011.html

Bakari, M., Ngadi, M., Kok, R., Raghavan, V., Diagne, A., 2010. Energy analysis for small- and medium-scale rural rice parboiling in sub-Saharan Africa, Second Africa Rice Congress, Bamako, Mali, 22–26 March 2010: Innovation and Partnerships to Realize Africa’s Rice Potential.

Bayart, J.B., Bulle, C., Koehler, A., Margni, M., Pfister, S., Vince, F., Deschenes, L., 2010. A framework for assessing off-stream freshwater use in LCA, Int J Life Cycle Assess 15, pp. 439–453.

Brüning, K., Boysen, U., Ayeni, J., Agamah, S.E., 2013. Competitive African Rice Initiative (CARI), Technoserve / GIZ 2013. Country Document Nigeria.

Gustavsson, J., Cederberg, C., Sonesson, U., 2011. Global food losses and food waste; extent, causes and prevention, study conducted for the International Congress SAVE FOOD! at Interpack 2011 Düsseldorf, Germany. FAO 2011. Retrieved from URL: http://www.fao.org/docrep/014/mb060e/mb060e.pdf

FAO, 2012a. Food security data and definitions. Retrieved from URL: http://www.fao.org/economic/ess/ess-fs/fs-data/ess-fadata/en/

FAO, 2012b. Food Wastage Footprint – Interim report FAO NRDD. Retrieved from URL: http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_FOOD-WASTAGE.pdf

FAO, 2014. FAOSTAT database, Food and Agriculture Organization, Rome, Italy. URL: http://faostat.fao.org

ILCD, 2011. European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union.

IPCC, 2006. Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Retrieved from URL: http://www.ipcc-nggip.iges.or.jp/

ISO, 2006. International Standard, ISO 14040, Environmental management – life cycle assessment – principles and framework. Geneva: International Standard Organization.

Longtau, S.R., 2013. Multi-agency partnerships in West African agriculture: a review and description of rice production systems in Nigeria, Eco-systems Development Organisation.

NBS, 2012. The Nigeria Poverty Profile 2010 Report of the National Bureau of Statistics (NBS), Harmonized Nigeria Living Standard Survey (HNLSS).

Oguntade, 2012. Reducing food losses to improve food security: An analysis of rice and rice value chains in Nigeria, report delivered to GIZ 2012.

PE International, 2013. GaBi 6 Software-System and Database for Life Cycle Engineering. PE INTERNATIONAL AG, Copyright, TM. Stuttgart, Echterdingen 1992 - 2013.

Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impact of freshwater consumption in LCA. Environmental Science& Technology 43, 4098-4104.

Roth, C., Volkmer, H. (Ed.), 2014. Micro-gasification: cooking with gas from dry biomass. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn and Eschborn, Programme “Poverty-oriented Basic Energy Services (HERA) ”.

Thylmann, D., Druzhinina, E., Deimling, S., 2013. The ecological footprint of cassava and maize post-harvest-losses in Nigeria - A Life Cycle Assessment, PE INTERNATIONAL AG. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of German Federal Ministry for Economic Cooperation and Development (BMZ).

Vermeulen, S.J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J., Hansen, J.W., Ingram, J.S.I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G.C., Thornton, P.K., Wollenberg, E., 2012. Options for support to agriculture and food security under climate change. Environmental Science and Policy 15, 136–144.

WRI, 2009. World Greenhouse Gas Emissions: 2005, updated version; Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, WRI, Washington. Retrieved from URL: http://www.wri.org/publication/navigating-numbers.