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A survey of on-farm uses of rice (*Oryza sativa* L.) by-products in Mwea rice irrigation scheme, Kenya

Gideon Kalii Muli[1], Alex Machio Kange[*2], John Byalebeka[1]

[1]*Faculty of Agriculture, Uganda Martyrs University, Uganda*

[2]*School of Pure and Applied Sciences, Bomet University College, Bomet, Kenya*

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Abstract

Rice (*Oryza sativa* L.) farming has received considerable attention in developing countries due to its significant contribution to smallholder farmers' incomes and food security. In addition, its by-products, rice straw and husks can be used as animal feed, making biochar/ briquette's, organic manure and also to make furniture. Therefore, the objective of this study was to assess the available quantities and uses of the rice by-products, rice straw and husks at farm-level and rice mills in Mwea Rice Irrigation Scheme (MRIS) located in Kirinyaga County in central Kenya. A survey of 300 randomly selected rice farmers and a number of rice hulling mills was conducted using a semi-structured questionnaire in the five rice blocks (Karaba, Mwea, Tebere, Thiba and Wamumu) of MRIS. The results revealed that 67% of the farmers had medium sized (1-10 acres) rice fields, with 84% of the farms producing 21-30 bags (each 90kg) of milled rice per acre. This rice yield was resulting from large quantities of rice straw and husks, with 70% of the straw being used to feed livestock and 55% of rice husk (RH) being used in making biochar. Rice straw and husks have great potential for domestic and industrial processing, the straw as source of livestock feed and husk as source of preparation of activated carbon.

* **Corresponding Author:** Alex Machio Kange ✉ gideonkalii@gmail.com

Introduction

Rice (*Oryza sativa* L.) is one of the important food crops for at least 50% of the world's population (Ahmed and Anang, 2019) and significantly influences food security in most countries (Ara *et al.*, 2017). Globally, over 100 million hectares of land is estimated to be under rice cultivation with an annual production of over 400 million metric tons (Kadipo *et al.,* 2021). The area under rice represents 29% of the total output of grain crops worldwide with Africa accounting for about 10 to 13% (Atera *et al.*, 2018). Currently, rice is grown in over 75% of the 54 African countries and its territories, with a total population of nearly 800 million people depending on rice for their food and livelihoods (Africa Rice Centre, 2009). Atera *et al.* (2018) reported that rice is the fifth most important cereal in terms of acreage and fourth in production in sub-Saharan Africa. The demand for rice has increased steadily in the recent decades thus, playing a major role in the strategic food security planning policies for several countries (Atera *et al.*, 2018). In SSA, the production of rice increased from 8 to 21 million tons between 1980 and 2006 (FAO, 2007). The increase in rice output is attributed to land expansion of paddy field, increase in both population and incomes and due to changing of consumer preference in favour of rice in urban centers (Kijima *et al.*, 2006).

In Kenya, rice is the third most important staple cereal after maize and wheat (Kundu *et al.*, 2016), its demand in the country exceeds production and the gap between production and consumption is filled through imports to meet the domestic demand at a huge cost. The current rice production is estimated at 150,000 metric tons from about 25,000 hectares of land (Atera *et al.*, 2018). In recent years, Kenya has seen rice grow in importance as per capita consumption, particularly in urban areas, has increased far more rapidly than that for other cereal crops (Kundu *et al.*, 2016). Nearly 95% of the rice consumed is produced from government managed irrigation schemes and the remaining 5% under rain-fed conditions (Chakraborty, 2020). The irrigated areas cover about 13,000 hectares (ha) and include West Kano and Ahero (3,520 ha), Bunyala (516 ha) and Mwea Rice Irrigation Scheme (MRIS) (9,000 ha) (Chakraborty, 2020; Kundu *et al.*, 2016). The MRIS is a vital region for rice production; it serves as a crucial food basket for the nation (Kundu *et al.*, 2016). Rice production leads to large volumes of rice straw and husks as by-products with an estimated annual production of rice straw and husks of over 120,000 tons and 60,000 tons, respectively (Morimoto *et al.*, 2023). Rice husk is a by-product obtained from the outer cover of rice grains during milling. However, these rice residues are typically burned or discarded, contributing to CO, CO_2, and NOx gas emissions (Cao *et al.*, 2006), which results in human health damage, air quality degradation, and waste of resources (Zhang *et al.*, 2017). The large amount of CO_2 emissions aggravates the trend of global warming and lead to disasters. The rice by-products have attracted more attention due to environmental pollution and an increasing interest in conservation of energy and resources (Mehtra and Folliard, 1995). With the adjustment of rural industrial structures and the improvement of rural living conditions, straw and husks have gradually appeared as a regional, seasonal, and industrial surplus, and the phenomenon of random discarding and open burning is serious (Zhang *et al.*, 2008). Straw and husks carbonization technology, as one of the comprehensive utilization technologies, cannot only alleviate the shortage of fertilizer and fuel in rural areas, but also protect the ecological environment, thus making the waste into valuable resources without secondary pollution (Chen *et al.*, 2021).

Recent studies have shown the potential of rice straw and husks as valuable resources for sustainable agriculture as they are rich in organic matter and essential nutrients making them ideal materials for biochar and compost (Demir and Gülser, 2021). Compared to other carbon management methods such as incorporation of the straw or husks into the field (Seyfferth *et al.*, 2019). Other studies have shown that biochar application in farmland can effectively increase soil organic carbon content, improve soil physical and chemical properties (Krapfl *et al.*, 2014) and reduce greenhouse gas emissions (Chen *et al.*, 2021). This study examines a survey of on-farm uses of rice by-products in MRIS, Kenya.

Materials and methods

Description of the study area

This study was conducted in the Mwea Rice Irrigation Scheme (MRIS) located at 0.6591° S, and 37.3827° E in Kirinyaga County, Kenya (Fig. 1). The scheme occupies the lower altitude zones of the region with expansive low marshy areas at an altitude that ranges from about 1,000 to 2,100 m above the sea level, temperatures ranging between 15°C and 30°C. The MRIS area experiences bimodal types of rains with the short rains occurring from October to December and the long rains occur between March and May. The main agricultural activity is mono-cropping of rice grown in paddies that are irrigated for at least six months. The main sources of water for MRIS are the River Nyamindi and River Thiba which are tributaries of the River Tana. Soils in the area are predominantly Vertisols, characterized by imperfectly drained clays, very deep, dark grey to black, firm to very firm and prone to cracking with a pH range of 4 to 6 (Kundu *et al.*, 2016). There are nearly 700 households within the MRIS (Kadipo Kaloi *et al.*, 2021).

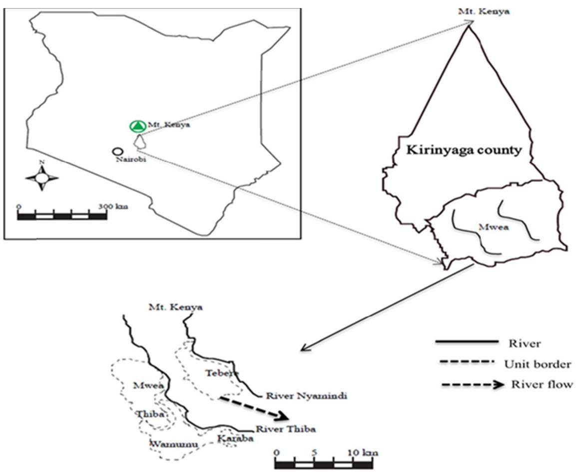

Fig. 1. Map of the Mwea rice irrigation scheme in Kirinyaga county

Study design, determination of sample size and data collection

A survey was carried out on 8th to 12th April, 2024 using a structured questionnaire. The questionnaire covered the uses of rice by-products on-farm uses of rice by-products in MRIS. In each of the following five units (Karaba, Mwea, Tebere, Thiba and Wamumu) of MRIS 30 farmers were interviewed. In every unit of the MRIS, a stratified random sampling method was used to identify farmers to be interviewed. The agriculture extension officers from the Ministry of Agriculture and well trained enumerators facilitated the survey by personally taking the surveyor to individual farmers' homes and helping in the sampling of the farmers to be interviewed. This was very helpful because of the language barrier and the requirement of obtaining a representative sample. In addition, key informant interviews were undertaken for the qualitative data. The sample size of rice farmers was determined using Cochran's sample size formula (Cochran, 1963). A total of 30 rice farmers were sampled per unit to give a total of 300 respondents. The data collected included rice yield (90 kg bag), quantities of rice straw and husks and their importances. Accuracy of the data collected was ensured by pre-testing the questionnaire on rice farmers in MRIS after which errors were corrected and omissions added to the questionnaire before the actual survey was carried out.

Data analysis

The information obtained from the questionnaire was coded onto a numerical scale and entered into a spreadsheet. Descriptive statistics using Statistical Package for Social Sciences (IBM SPSS Statistics Version 20.0) were later carried out on the data. Descriptive statistics involved using the frequencies command to determine measures of central tendency (mean and percentage).

Results and discussion

Rice in the field was attacked by pest such as snails (88.0%), birds (10.3%), the common disease in rice field was rice blast (96.7%) (Table 1). A majority (97.0%) of the rice farmers harvested their rice at physiological maturity (PM), using combine harvester (86.7%). They threshed it using motorized drum thresher (55.0%) and hand (43.4%) and it was milled (100 %). Rice yield was 21-30 bags (90 kg) of milled rice per hectare was (84.3%) with the major storage pest being rats (98.7%).

Table 1. Rice harvesting, by-products and yield

Characteristic	Frequency	Percentage
When is rice harvested		
Physiological maturity	291.0	97.0
Past physiological maturity	9.0	3.0
Field insect pests that attack rice		
Snails	264	88.0
Stem borers	5	1.7
Birds	31	10.3
Total	300	100.0
Rice diseases common in the rice fields		
Rice blast	290	96.7
Brown spot	1	0.3
Narrow brown leaf spot	9	3.0
Total	300	100.0
Rice harvesting is done by		
Sickles	40	13.3
Combine harvester	260	86.7
Total	300	100.0
Threshing of rice		
Hand threshing	130	43.4
PTO driven thresher	5	1.6
Motorized drum thresher	165	55.0
Total	300	100.0
Rice is milled by		
Rice mills	300	100.0
Total	300	100.0
Number of rice bags (90 Kgs) milled per acre		
< 10	5	1.7
11 - 20	7	2.3
21 - 30	253	84.3
31 - 40	25	8.3
> 41	10	3.3
Total	300	100.0
Storage pests that attack rice		
Rice weevils	4	1.3
Rats	296	98.7
Total	300	100.0
Control practices for pests		
Synchronized sowing of rice in large area	9	3.0
Integrated pest management	251	83.7
Harvesting rice at ground level	4	1.3
Scare crow	36	12.0
Total	300	100.0
Tones of husks in milled		
1 - 2	1	0.3
3 - 4	76	25.3
> 5	224	74.7
Total	300	100
Uses of rice husks		
Make carbonized RH	92	30.7
Make RH briquettes	41	13.7
Making RH boards	1	0.3
Making biochar	165	55.0
Total	300	100.0
Uses of rice straw		
Plough back into the fields	20	6.7
Selling in the market	69	23.0
Making compost	1	0.3
Livestock feed	210	70.0
Total	300	100.0

Rice yield in upland ecosystems in Kenya is about 1 ton/ha (Kijima *et al.*, 2006). The low yield of rice in upland conditions is due to constraints such as nutrient depletion, in the soil, loss of organic matter, pests and disease incidences such as bird damage, rice blast (Bruce, 2010). Thus, any future increase in rice production will only come as a result of improved yields, through expanding the area under production and reducing field and storage losses (Orke and Dehne, 2004).

The main rice by-products generated through the different processes of rice production are rice straw, RH and rice bran (Uma *et al.*, 2022). The important by-products are husks, comprising of about 20% of paddy rice and rice straw mass (Byerlee *et al.*, 2010). The rice husk is the outermost covering of the paddy grain that is separated from rice grains during the process of milling. It is the coating on a seed or grain of rice formed from hard materials, including silica and lignin, to protect the seed during the growing season (Uma *et al.*, 2022). It is said to have an average composition of 80% organic matter and 20% ash (Bisht *et al.*, 2020) and around 20-22% of the paddy weight is husk (Finance Tribune, 2015). Rice husk contains approximately 20% silica which is presented in hydrated form (Javed *et al.*, 2008). Rice husk is naturally tough, woody, water insoluble, and has abrasive resistance behaviour and silica-cellulose structure (Bisht *et al.*, 2020). The exterior is mostly silica coated with a thick cuticle and surface hairs, while small amount of silica is presenting the mid-region and inner epidermis.

Rice husks were being utilized by the rice farmers in various ways with a majority of them (55%) making biochar. RH has a calorific value of 15217.20 KJ/Kg, with an efficiency of boiler found to be the same as using of coal (68%), so RH is cheaper fuel than coal (Babaso and Sharanagouda, 2017). The RH produces heat energy by direct combustion and gasification and it can be used for several processing such as generation of steam in parboiling of rice (Shwetha *et al.*, 2014; Yadav and Singh, 2015). Rice straw is potentially used for electric generation as 1 tonne of RH is required for producing 1 MWH electricity. It is also used as alternative fuel for household energy (Rozainee *et al.*, 2008). Reaction involved in fuel reactor according to composition of RH with 1 mole C, 0.6402 moles hydrogen (H_2), 0.3052 oxygen (O_2) as follows (Monga *et al.*, 2015). The densified form of RH is pellets and briquettes, due to increased density; combustion performance of these by products is superior to unground RH. Briquettes and pellets are frequently utilized in lieu of fossil fuel in industrial boilers (Chakraborty, 2020).

Currently, organic fertilizer plays important role in agriculture, RH is utilized as an organic fertilizer to improve not only productivity but also water use efficiency in field (Babaso and Sharanagouda, 2017). Many studies have reported that RH is used to improve of nitrogen and other macro and micro-elements absorption thus enhancing the production and translocation of the dry matter content from source to sink (Ebaid *et al.*, 2007). The RH is bio-transformed of into organic fertilizer through vermicomposting (Shak *et al.*, 2013). Also it can be used as a source of potassium for growth and yield of crops (Priyadharshini and Seran, 2010).

According to 70% of the respondents, rice straw in MRIS, was mainly being used as livestock feed. This concurs with the finding of (Kilyenyi *et al.*, 2023) who found that the use of rice straw as livestock feed and as source of income (23.0%) to the farmers. The straw was ploughed into the rice field as exhibited by 6.7% of rice farmers which is agreement (Ahmed *et al.*, 2018; Danso *et al.*, 2019) noted that rice straw may be used as biochar in sandy soil for sustenance of transpiration of maize during drought situations (Shen *et al.*, 2014). Rice straw is the vegetative part of the rice plant and major forage in rice-producing areas (Uma *et al.*, 2022). It is separated from the grain during the harvest (Moraes *et al.*, 2014). For every tonne of grain harvested, about 1.35 tonnes of rice straw remains in the field (Buggenhout *et al.*, 2013; Moraes *et al.*, 2014). It is about 50% of the dry weight of rice, with significant variation from 40% to 60% according to the method of cultivation, field conditions and harvesting technique (Kadam *et al.*, 2000).

Conclusion

The study was undertaken to assess the use of rice by-products, husks and straw at MRIS as a strategy to the use of these residues are typically burned or discarded, contribute to CO, CO_2, and NOx gas emissions, which would result in human health damage, air quality degradation, and waste of potential resources in rice farming. Thus, MRIS and other stakeholders to focus more on the farmers who are more willing to take up on the use of rice by-products as feed and activated carbon.

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