Reducing post-harvest loss and waste along the rice supply chain and consumption

Esty A. Suryana[1], *Anna V. R.* Mauludyani[2*], Sumedi[1], *Mewa* Ariani[3], and *S. Joni* Munarso[4]

[1]Indonesian Center for Agricultural Socio-Economic and Policy Studies, Bogor, Indonesia
[2]Department of Community Nutrition, Faculty of Human Ecology, IPB University, Bogor, Indonesia
[3]Research Center for Behavioral and Circular Economics, National Research and Innovation Agency, Jakarta, Indonesia
[4]Research Center for Agroindustry, National Research and Innovation Agency, Bogor, Indonesia

Abstract. The land and water resources for rice production have declined due to climate change events, causing supply disruptions. From 2000 to 2019, cereal crop losses, including rice, comprised 13.4% of the domestic supply. Enhancing agricultural efficiency requires efforts to reduce rice loss and waste. This research aimed to analyse rice consumption patterns, estimate rice loss and waste, and formulate policy recommendations. Data from different institutions were descriptively analysed. The main findings are as follows: 1) with a consumption participation rate of 98.7% and an expenditure share of 95.5% of all cereals, rice is a staple food for Indonesians; 2) rice supply chain losses range from 12.7% to 20.1%, with harvesting losing the most at 7–10%; 3) household waste reaches 2.7–3.2 kg/capita/year; 4) a total of 10 million tons of dry unhusked grain (GKG) or 2 million hectares of harvested rice are lost and wasted. Farmers, traders, consumers, the government, and the private sector must share responsibility for addressing rice loss and waste. Encouraging post-harvest technologies, such as the usage of combine harvesters, as well as enforcing rules and fostering mentality shifts, are essential tasks. Consumers can prevent food waste by calculating the amount of rice they need to cook.

1 Introduction

In the future, meeting the population's food needs will become increasingly difficult. Global demand for agricultural products is estimated to increase by more than 63% between 2005 and 2050. A 70% increase in cereal production is urgently required [1,2]. The need for meat in developing countries will increase by 80% in 2030 and more than 200% in 2050. This increase results from increasing population and income, changing consumption patterns, and increasing urbanisation [3,4].

On the other hand, natural resources are increasingly scarce. Almost half of the forests have become denuded, groundwater sources are running low, and biodiversity is decreasing. Approximately 25% of agricultural land is experiencing severe degradation, negatively impacting crop productivity, the environment, and food security [5,6]. Another problem is

* Corresponding author: anna-vipta@apps.ipb.ac.id

global climate change, which disrupts ecosystems and the sustainability of food production [7].

This pattern is observed in nearly every nation, including Indonesia. Indonesia's population in 2010 was 270.2 million people, and the United Nations estimates it will reach 300 million people by 2050. Due to land conversion, rice fields shrank from 8.13 million hectares in 2013 to 8.09 million hectares in 2015 and are expected to continue diminishing. Land degradation is worsening due to land abandonment, leading to reduced productivity of dry lands. Climate change exacerbates the situation by reducing water availability in river basins and causing irregular rainfall patterns, including longer dry periods and extreme rainfall events [8].

One strategy to ensure sustainable food provision is to minimise food loss and waste, a growing concern worldwide. This is a key target of the Sustainable Development Goals (SDGs), which aim to halve global food waste per capita at the retail and consumer level and reduce food loss throughout the production and post-harvest processes by 2030 [9].

Indonesia faces significant challenges in this regard. It has the world's second-largest food loss and waste (FLW) levels, estimated at 300 kilograms per capita per year, following only Saudi Arabia [10]. Between 2000 and 2019, Indonesia experienced FLW ranging from 23 to 48 million tons per year, equivalent to 115 to 184 kilograms per capita per year. The largest portion of FLW is attributed to the food crops sector (46.2%), amounting to 14−24 million tons annually. Within this sector, the grains group (grain/rice, corn, wheat/wheat flour) accounts for the most significant portion, with FLW ranging from 12 to 21 million tons per year [11].

Every year, the government tries to increase rice production, considering that rice is the staple food of the Indonesian population. Whoever leads the government in Indonesia will still be preoccupied with the rice problem [12]. Furthermore, it is said that rice production patterns are still very dependent on the season. The year 2015 is proof that El Nino affected rice supply performance. Data from the Ministry of Agriculture shows that the rice harvest area in 2021 was 10.41 million hectares, with a production of 54.42 million tons of GKG or 34.8 million tons of rice. This production meets 98.9% of rice needs from domestic production. The Indonesian government is targeting rice production in 2024 of 46.8 million tons.

Based on several challenges and problems, this paper aimed to analyse rice consumption patterns, the level of rice loss during harvest and post-harvest processes, and consumer-level rice waste. By knowing this amount, alternative policies can be formulated to reduce the loss and waste of rice to realise efficient use of environmental resources.

2 Methodology

2.1 Materials

The expenditure data, participation rate, household rice consumption, and population figures for 2018–2022 were obtained from BPS-Statistics Indonesia. Similarly, data on non-household rice consumption and rice field area, production, and productivity were obtained from BPS-Statistics Indonesia and the Ministry of Agriculture. The rice loss and waste rates were obtained from various sources, such as the FAO and other research findings.

2.2 Methods

The data was analysed descriptively. The proportion of expenditure on rice was calculated by comparing the value of rice expenditure with other cereal grains. Rice loss encompasses

activities from harvesting to distribution, while rice waste was only assessed at the household level due to data limitations. The total quantity of rice loss/waste was obtained by multiplying the percentage of rice loss/waste found in research on rice production. The harvested rice area lost due to food loss and waste (FLW) was calculated based on the estimated total FLW divided by rice productivity. To convert the quantity of wasted rice into dry unhusked grain (GKG), a conversion factor provided by BPS-Statistics Indonesia (2018), which is 64.10 for the conversion from GKG to rice, was used.

3 Results and discussion

3.1 Rice as a staple food

Data from the National Socio-Economic Survey categorises food consumption into 14 groups, with one of these groups being grains. This category encompasses rice, sticky rice, wet corn with husks, shelled corn/corn rice, and wheat flour. Rice holds a special place as the primary staple food in Indonesian society, regardless of whether individuals reside in urban or rural areas. This is evident from various indicators such as rice expenditure, the participation rate of rice consumption, and the amount of rice consumption.

Rice expenditure accounts for a substantial portion of household budgets, comprising 95.1% in 2018 and remaining relatively stable at 94.1% in 2022. The participation rate in rice consumption, which reflects the proportion of individuals consuming rice, has consistently remained high over the past four years, consistently exceeding 96%. In contrast, the participation rate for cassava consumption, another carbohydrate source that could potentially substitute for rice, is only around 28% in 2022 (Table 1).

Table 1. Participation rate and consumption of rice and cassava.

Year	Consumption participation rate of rice (%)	Consumption participation rate of cassava (%)	Rice consumption (kg/capita)
2019	96.8	21.6	77.5
2020	97.0	24.0	77.4
2021	97.7	30.2	80.4
2022	98.7	28.2	79.9

Source: [13,14]

This significant disparity in participation rates between rice and cassava indicates that rice's position as the primary staple food in Indonesia remains unchallenged. Despite government efforts to promote diversified staple food consumption, primarily through food diversification programs, people's deeply ingrained food habits remain. Rice is so deeply embedded in Indonesian food culture that many people consider a meal incomplete if it does not include rice. This is a significant factor contributing to the limited success of food diversification efforts [15].

Rice consumption in Indonesia has experienced fluctuations, particularly during and after the pandemic. In 2019, the average per capita consumption of all types of rice, including local, superior quality, and imported rice, stood at 77.5 kg. This consumption figure then slightly decreased to 77.4 kg/capita in 2020. However, as the second year of the pandemic unfolded, rice consumption rebounded, reaching an average of 80.4 kg/capita in 2021.

Rice plays a crucial role not only in households for direct consumption but also in various other sectors such as industry, hotels, and services. According to the BPS-Statistics Indonesia Staple Food Consumption Report for 2015–2019, most rice consumption, amounting to 74.7% or approximately 20,685,619 tons, came from households in 2019 (Table 2). This translates to an average of about 77.5 kg/capita/year. These statistics underscore the central importance of rice in the diets and overall consumption patterns of the Indonesian population. In 2015, the total rice consumption was approximately 29,178,940 tons, equating to around 114.6 kg/capita. This figure declined to 29,133,514 tons or 111.59 kg/capita in 2017 and further decreased to 28,692,107 tons or 103.7 kg/capita in 2019. These numbers reflect an overall descending trend in rice consumption despite fluctuations in specific sectors like hotels, restaurants, and catering.

Table 2. Household and non-household rice consumption.

Rice consumption	2015		2017		2019	
	kg/capita	%	kg/capita	%	kg/capita	%
Household	84.90	74.1	81.60	73.1	77.50	74.7
Non-household	29.72	25.9	29.98	26.9	26.25	25.3
a. Industry	10.11		7.77		1.75	
b. Hotel, restaurant, catering	18.72		22.08		24.37	
c. Service	0.89		0.13		0.13	
Total	114.61	100	111.59	100	103.74	100

Source: [16]

3.2 Food loss and waste for rice

Food waste occurs from production to table. Losses are found in harvesting, processing, transportation, marketing, and consumption [17,18]. Food loss occurs along the food supply chains, while food waste occurs at the consumer, retail, or food service level [19,20]. In contrast to food FLW, research on FLW in the form of commodities is still rarely carried out. Previous studies on the level of food loss for rice were presented in Table 3, while consumer-level rice waste was shown in Table 4.

Many factors influence the rate of rice loss. Apart from the impact of the way of handling and use of harvesting equipment, there are the rice varieties planted, harvest age, the behavior of farmers and growers, and the ecosystem [21]. After harvesting, post-harvest rice activities include threshing, transportation, drying, milling, storage, and marketing. Based on the data in Table 3, each study grouped post-harvest activities differently; some are directly detailed, but some are presented in their aggregates. A finding from a study showed that the level of rice yield loss during harvesting and post-harvest was 20.1%, with the dominance of harvesting and threshing activities [22]. Rice losses of 66% occurred in harvesting, stacking, and threshing activities in the fields, while 34% occurred in drying and storage activities at home [23].

Another study in 2020 showed that the rate of rice loss was 12.7%, lower than a previous study conducted in 2016 [22,24]. This is thought to be because farmers have started using harvesting equipment with combine harvesters, threshers for threshing, assistance with

cultivation, and post-harvest technology. Thus, this had an impact on reducing rice losses. The results of another study show that farmers in Central Java use combine harvesters (22%) and dryers (23.5%) [25]. One hundred per cent of harvest activities in Peninsular Malaysia use combine harvesters [26]. In the case of Jambi Province, 80–85% of the land area already uses combine harvesters [27].

Table 3. Food loss for rice during harvesting and post-harvesting.

No	Source	Agricultural activity	Food loss (%)
1	[24]	Harvesting	7.2
		Reaping	1.27
		Threshing	1.74
		Drying	2.48
		Total	**12.7**
2	[28]	Harvesting and post-harvesting	11−13%
3	[22]	Harvesting	9.52
		Threshing	4.78
		Drying	2.13
		Milling	2.19
		Field transportation	1.50
		Total	**20.12**

Consumer-level rice waste can occur in households, hotels, catering, café, hospitals, prisons, and other places where rice-eating activities occur. The rice waste in households is around 2.7–3.4 kg/capita/year, while it reaches 29.7 tons/year in restaurants.

Table 4. Food waste for rice on the consumer level.

No	Source	Location	Unit	Food waste
1	[29]	Household in Jakarta, Bogor, Depok, Tangerang, Bekasi	kg/capita/year	2.7
3	[30]	Household in Bogor	kg/capita/year	3.4
4	[31]	Six small restaurants, four medium restaurants, three luxury restaurants in Bogor	ton/year	29.7

The national FLW for rice must be determined after thorough research. National FLW estimations are derived from existing FLW research data because the outcomes of FLW research are still limited. The rate of rice loss from harvest to distribution was obtained from the average calculation results using a loss rate of 12.7% and 20.12%, respectively [22]. Rice waste is only calculated at the household level, obtained from the average rice waste from two studies [29,30]. Based on this, the level of loss and waste equivalent to GKG during 2018–2021 is around 10 million tons (Table 5). Using data on productivity and harvested area for that period, the rice harvest area lost due to FLW is between 18.7% and 21.0% of the total harvested area. When data from new and thorough study findings are established, the FLW volume of rice expressed in tons of GKG/rice and the area in hectares will change.

Table 5. Total loss on rice harvested land due to FLW, 2018−2021.

Variable	2018	2019	2020	2021
Harvested land (000 ha)	10,903.8	10,677.9	10,657.3	10,515.3
Productivity (q/ha)	51.85	51.14	51.3	52.6
Production of GKG (000 ton)	56,537.8	54,604.0	54,649.2	55,269.6
Loss of GKG due to harvesting and post-harvesting (000 ton)	9,277.9	8,960.5	8,967.9	9,069.7
Waste from households equivalent to GKG (000 ton)	1,256.9	1,270.0	1,282.8	1,297.5
Total FLW (000 ton)	10,534.8	10,230.5	10,250.7	10,367.2
Total loss of harvested land due to FLW				
Total (000 ha)	2,031.8	2,000.5	1,998.2	1,971.0
% of current harvested land	18.63	18.73	18.75	20.97

Source: [37]

This FLW level is relatively large even though the government has provided incentives for farmers and other business actors to increase harvest area. As an illustration, in 2015, the government, through the Ministry of Agriculture, established a special program to increase rice production through improving irrigation and other supporting facilities. The rice field extension program in 2016 reached 129 thousand hectares, an increase of 643.2% compared to 2014. Another program is intensive assistance involving the National Army and Ministry of Agriculture employees and regular reporting of added planting area data [32].

On the other hand, growing rice uses environmental resources. Transplanted rice usually receives 1,000–2,000 mm of water input, depending on the growing season, soil type, climate, and hydrological conditions. Reducing this crop's water need is challenging in light of water constraints and climate change [33]. Thus, FLW rice certainly has a negative impact on various aspects of life. The amount of rice ready for consumption is decreasing, threatening food security and reducing incomes [23,34,35]. FLW is a wasteful use of environmental resources and the state budget [36].

3.3 Strategy to reduce FLW for rice

FLW has a negative impact on climate change and natural resource sustainability [19]. A land footprint of 9.58 ± 0.4 million ha and carbon footprint of 64.1 ± 3.8 Mt CO_2 eq in India, a 1.23 million ha of harvested land and 413 million m^3 of water resources in Japan, and a 30–50% greenhouse gas emission increase in Myanmar is caused by losses along the rice value chain from farming to milling [38–40]. In Indonesia, the loss of 9.9 thousand tons of rice results in a loss of 379 kcal of energy and 8.87 grams of protein per person daily [22]. With the FLW expected in this study and when combined with food waste in public services, such as restaurants and hospitals, energy and protein losses would undoubtedly be greater. Increased FLW for rice will harm rice sufficiency, further harming food and social security.

Hence, lowering FLW for rice can ease the production burden and promote the growth of sustainable agriculture. The people, notably the rice industries and consumers, support the government in this effort. For that reason, greater awareness and a change in perspective are essential.

The primary reasons for rice loss are a lack of knowledge and skills, inadequate and ineffective harvesting methods, poor infrastructure and logistics, and insufficient storage

facilities [41–43]. To address this issue, lowering crop losses and raising farmer income are the primary objectives to reduce food loss. Consequently, it is believed that farmers will be encouraged to use technology, actively formulate policies and programs directly or indirectly related to limiting food loss and engage in these efforts.

There is a high level of grain loss in Indonesia during harvesting; therefore, reducing losses during harvesting activities will significantly reduce rice losses. Harvesting with a sickle should be replaced with more cost-efficient and time-saving tools that minimise yield losses. The choice of harvesting equipment and its size can be adjusted to the conditions of the farmer's land. Harvesting equipment produces good-quality grain, is easy for farmers to operate, and is easy to service and get spare parts. Collective farmers who are members of farmer groups make it easier to decide on the choice and application of the harvesting equipment used. In the case of Jambi, the rice harvest loss rate with a combine harvester is only 4.1–5.4%; when using manual human power, it reaches 16% [27]. As presented by Munarso and Kailaku at the Workshop on Food Loss and Waste (FLW), Meeting of Agricultural Chief Scientists G20 in Yogyakarta, Indonesia, 2022, using harvesting equipment such as combine harvesters, strippers, movers, and reapers resulted in 1.2%, 2.5%, 3.9%, and 7.9% yield losses, respectively. Using a combine harvester will also reduce losses during collection and threshing, allowing reduced food loss.

Farmers in all regions, especially in rice production hubs, will use harvesting equipment more quickly with the help of the national and regional governments. Like this, further methods are required to lower rice output losses. In the early stages of policies and programs, funds will be used to purchase equipment, help, and other costs. Yet, this investment in the following stage will yield returns with effective use of the funds allotted for rice production. Total rice losses during the supply chain were decreased from 6.9% to 2.6% by using 100% more combine harvesters, transport equipment, drying machines, and rice storage places in China [44]. China will save 540 thousand tons of rice, 78 thousand hectares of land, and 26 thousand tons of chemical fertiliser if losses are reduced from 3.02% to 2.76% [45].

Consumer behaviour that results in food waste is influenced by various factors, including eating excessive food, particularly during social gatherings away from home. Every single person eats rice due to its status as a staple food. In families, everyone often finishes the rice they take. However, it is common that more rice is cooked than the family requires, resulting in a waste of the extra rice, which is then thrown away or stale. Cases in restaurants and hospitals are similar. Therefore, food waste for rice is reduced by planning well and cooking the accurate amount of rice each day in the household and food services. Housewives and heads of food services play an important role in this. The government can issue regulations by providing incentives and disincentives for consumers and business actors who waste food, including rice.

4 Conclusions and policy recommendations

Rice is the main staple food of the Indonesian population. To meet this need, the government is trying to fulfil it from its own production by establishing a rice production and productivity program. However, from the average rice production in 2018–2021, around 10.5 million tons of GKG could not be utilised because it was lost or scattered during harvest to distribution and wastage in households. The greatest grain loss was during harvesting (7.2–9.5%), followed by threshing and drying. Therefore, efforts to reduce grain loss are prioritised in rice harvesting using a combine harvester. Combine harvesters should be implemented massively, covering not only rice production centres but also other areas, especially where harvesting labour is limited. The choice of size and type of harvesting equipment, such as strippers and movers, is adjusted to the land topography. To reduce rice waste, good planning to determine the amount of rice cooked every day by consumers and food services is essential.

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