Increasing rice farmers' income through added value and implementing a circular economy

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Abstract. Rice farming is an important economic activity in the national economic setting because it provides employment opportunities for rural families and produces rice as a main staple food for Indonesians. However, rice farmers face an economy of scale issue due to small-scale farming, where around 80% of rice farmers cultivate less than 0.5 ha with an average income from rice farming of approximately IDR 5.46 million/ha/season. This income is obtained only from grain production, whereas parts of the rice plant have the potential to be processed and generate revenue. This study aims to identify opportunities to increase rice farmers' income by creating added value and processing rice by-products, based on a circular economy approach. The method used was a literature review from published scientific journals supported by secondary data analysis. The study results indicate opportunities to increase rice farmers' income by utilising straw for organic fertiliser, husk for biochar, many parts of plants for animal feed, and rice bran for functional food. This study recommends that to implement these economic circular activities efficiently, farmers have to work in farmer group organisations such as farmer corporations or farmer-owned enterprises.

1 Introduction

Rice is one of Indonesia's most important and vital food crops. Rice is the staple nourishment for practically all people in the country. With a population of 276 million (2023) and per capita consumption of 111.6 kg/year, the country's rice needs for human consumption is about 31 million tons. Conversely, millions of Indonesian farmers rely on rice farming as a source of income [1]. There are several difficulties in raising rice production over time to fulfil the growing consumption needs, namely (i) reduction in the rice field acreage nationally due to land conversion, (ii) increase in crop failure occurrence due to climate change, (iii) increase in the impact of the Russian-Ukrainian war, and (iv) a relatively small area of land being used for rice farming [1–4]. Low farmer productivity and income result from small-

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scale rice farming. Eventually, rice farmers will switch to growing more lucrative crops if rice production becomes unattractive due to low returns. Therefore, it is crucial to pay attention to initiatives to improve the welfare of rice farmers.

Without considering the potential income that could be generated from parts of a rice plant, farmers' income from rice farming is mainly derived from the value of the grain harvest. Straw from the rice plant, which has not been used and has the potential to earn farmers more money than grain, is one such possibility [5]. Additionally, the by-products of turning grain into rice, such as bran and rice bran, which may be utilised as animal feed and functional food items, can boost the profitability of rice farmers. Based on this assessment, this study aims to identify opportunities to increase rice farmers' income by creating added value and processing rice by-products, based on a circular economy approach.

2 Methodology

The method used in this study is a literature review from published scientific journals supported by secondary data analysis. The coverage of this analysis is at the national level for the last seven years (2016-2022). Data and information on the rice economy and policies were gathered from BPS-Statistics Indonesia, the Indonesian Ministry of Agriculture, and other relevant institutions to enrich the discussion.

The literature review in this work, which adheres to the research objectives, is restricted to quoting data and materials from earlier studies to find ways to raise the added value and better use rice trash and by-products to increase the income of rice farmers. The study of rice farming, rice farmer income, the number of families engaged in rice farming, and the findings of the analysis of by-products and rice waste processing are the primary topics covered by secondary data from BPS-Statistics Indonesia and other institutions.

3 Results and discussion

3.1 Rice farming performance and farmers' income

3.1.1 Area of cultivation and number of rice farmers

In 2022, the paddy fields in Indonesia were 7.46 million ha, with a harvested area of 10.61 million ha [6]. Most rice farming is carried out in paddy fields (*sawah*), and approximately 49% of the paddy fields are on Java Island. Expanding food crop production, particularly that of rice, faces significant limitations. Only 2.2 million hectares of potentially suitable land exist, mainly in remote, mineral swamp areas of Papua. This limited resource, coupled with accessibility challenges, hinders efforts to expand rice production for long-term national food security [3].

Data from the Inter-Censal Agricultural Survey 2018 (SUTAS2018) shows that the number of households working in agriculture was 27.68 million units [1]. Furthermore, SUTAS2018 data shows that among agricultural households, 16,26 million households (59%) operated land of less than 0.5 ha and are referred to as smallholders. The average size of land ownership for rice fields per household farmer is only around 0.18 ha. Smallholder farmers increased by more than 1.5 million households (around 11%) compared to data from the 2013 Agricultural Census.

3.1.2 Rice farmers' income

BPS-Statistics Indonesia data shows that in the 2017 planting season, the total cost per hectare of rice farming was IDR 13.56 million. The most significant components of production costs for lowland rice farming were workers' wages and agricultural services, which reached 48.79% of the total costs or IDR 6.62 million [7]. Furthermore, the relatively large components of production costs were land rental and fertiliser expenses, which amounted to 25.61% (IDR 3.47 million) and 9.43% (IDR 1.28 million) of the total costs, respectively. Meanwhile, the production value was IDR 18.51 million/ha/planting season. Based on this data, the income from lowland rice farming was IDR 4.95 million/ha/season. With an average lowland rice farmer's cultivation of 0.3 ha, the household income of lowland rice farmers was around IDR 1.65 million/season. With an average number of household members of four per household, the rice farming income was IDR 0.41 million/capita/season or IDR 0.14 million/capita/month.

The research results in Central Lampung District show that seeds, urea fertiliser, NPK fertiliser, manure, labour, and land acreage significantly affected rice production. In contrast, KCl and SP36 fertilisers had no significant impact on rice production [8]. The rice farming revenue over cash costs was IDR 16.79 million/ha with an R/C ratio value over cash costs of 3.69, which means that rice farming is profitable because the R/C value is more than one.

Research in West Java shows that with an average cultivated area of 0.69 ha, the average rice revenue was IDR 11,32 million, while the farming costs were IDR 4.01 million [9]. Converted to one hectare, the profit generated from this rice farming, including the by-product value (IDR 103.2 thousand), was IDR 10.27 million, with an R/C of 2.89. Compared with the total household income, rice income is only 23.31%. With a cultivated area of 0.69 ha, income from rice farming is not sufficient for the daily needs of these farmer households, so farmers need additional income from other sources. Other income sources were agriculture, excluding rice (56.13%) and the non-agricultural sector (20.56%).

The research results in the Mlonggo Sub-district, Jepara District, Central Java Province, show that the average production was 1,947 kg/season/0.5 ha [10]. The average production cost incurred by farmers was IDR 7.53 million/0.5 ha. The average revenue of rice farming was IDR 16.45 million/0.5 ha, so the average income was IDR 8.92 million/0.5 ha. The average monthly income of farmers was IDR 1.49 million, which was lower than the regional minimum wage (UMR) for Jepara District, which was IDR 1,600,000. The factors influencing rice farmers' income were pesticide and land costs. Meanwhile, fertiliser, seed, and labour costs do not affect the income of rice farmers in the Mlonggo Sub-district.

The research results in rice farming in coal mining areas in Kutai Kartanegara District, East Kalimantan Province, show that the average cost of producing rice was around IDR 9.76 million/season, the average revenue was IDR 13.42 million/season, and the average income was IDR 3.66 million/season [11]. There are differences in income between lowland rice farming around coal mines and lowland rice farming not around coal mines.

Productivity, selling prices, and production expenses of rice farming operated by a single farmer were the key elements determining farmers' revenue from the rice industry in Maros District, South Sulawesi Province [12]. According to an analysis of panel data collected from farmer households in many Indonesian areas with good irrigation facilities (PATANAS data 2010, 2016, and 2021), better seeds and inorganic fertilisers increased rice yields [13]. In West Sumatra Province, the amount of farmed land, price of rice, number of seeds planted, use of fertiliser, and number of labourers all affected the revenue of rice farmers [14].

From the discussion above, it can be concluded that rice farming in various regions and ecosystems in Indonesia is feasible, but does not provide sufficient income for small-scale farming families. The average acreage of rice farming per household was very small. Rice farming income only takes into account income from the value of grain or rice and does not consider the importance of by-products or processed waste.

3.2 Circular economy approach, increasing added value and farmers' income

3.2.1 Circular economy approach

The circular economy proposes a transformative approach – a way of life where nature thrives and resources are used endlessly. This model prioritises keeping materials in circulation through repair, reuse, and various recycling techniques, such as remanufacturing and composting. By decoupling economic growth from resource depletion, the circular economy tackles climate change and other pressing global challenges, including waste accumulation, pollution, and biodiversity loss.[15].

The circular economy is built on three design-driven tenets: (i) reducing waste and pollution, (ii) recycling materials and products at their best value, and (iii) regenerating the natural world. The circular economy, supported by a shift to renewable energy and materials, is a robust system for organisations, people, and the environment [15].

Current economic systems often generate waste by discarding materials after use. However, the circular economy, championed by the Ellen MacArthur Foundation [15], offers a transformative alternative. It envisions an industrial system designed for restoration and regeneration in which materials retain their value throughout their lifecycle. The ultimate aim of this approach is to break the link between economic growth and environmental pressure [16]. In simple terms, the circular economy strives for zero waste and pollution. It encompasses all stages of a material's journey, from extraction from the environment to processing within industries, and ultimately reaching consumers. Every step in this cycle considers the impact on all ecosystems involved. The implementation of a circular economic approach is expected to align with efforts to create a healthy environment while optimising the use of by-products and waste to create new useful products that increase economic value.

By definition, waste is any material resulting from human activity or a natural process and has no or very little economic value [17]. It has been claimed that waste has relatively little economic value because treating it is expensive and might cause environmental pollution. Waste can be used in diverse ways to raise its economic worth. Agricultural waste can be further processed to produce valuable by-products in addition to the primary commodity using proper and innovative technologies.

Numerous studies on the subject of rice growing have revealed that numerous by-products and waste from the practice have not been fully exploited [18]. However, according to the findings of various studies, it is possible to apply processing technologies to use waste and by-products from the rice-growing industry [19]. Rice farming waste materials, including straw, husks, and bran, may boost the added value and household income of rice producers. A circular economy strategy can be used for the use of rice by-products.

A study conducted in Sri Lanka shows the potential for utilising rice industry by-products in the form of rice husk, rice straw, and rice bran to become compost, energy sources, biochar, and other uses, as depicted in Fig. 1. [20].

The description of the circular economy approach used in Sri Lanka can be adopted in Indonesia and potentially increase rice farmers' income. This strategy can be implemented through collaborative partnerships between the industrial sector and rice farmer groups. The farmer group is a supplier of industrial raw materials in the form of rice straw, rice husk, and rice bran, and the industrial sector further processes these raw materials into various processed products.

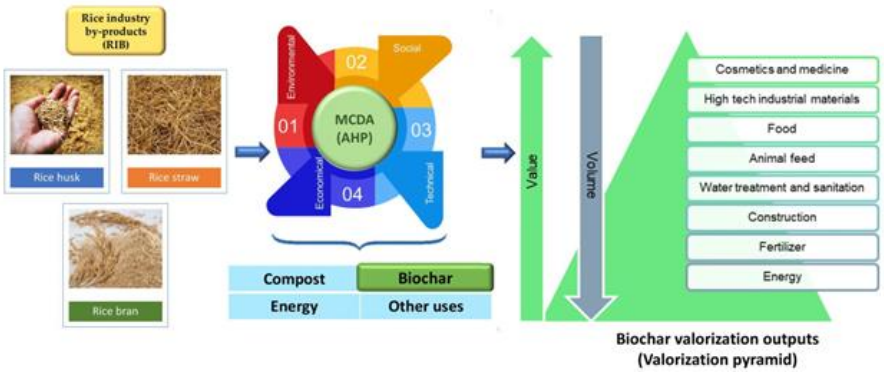

Fig. 1. Circular business model of rice industry by-products.
Source: [20]

3.3 Increasing added value and farmer income through the use of by-products and rice waste

Straw, husks, and rice bran are by-products and examples of rice waste. After the grains are separated from the stalks of cereal plants, straw is a by-product of the agricultural industry [14]. Straw can be used as building material (roofs, walls, and flooring), fuel, animal feed, cage mats or floors, packaging for agricultural products (such as eggs), mulch, and handicrafts. By converting them into biochar, straw enriches agricultural soil nutrients as well. Additionally, rice straw can be used to grow mushrooms and produce energy from ethanol, biogas, and bio-oil for direct combustion [18]. Goodman [18] showed that using rice straw can be an opportunity to increase the added value and income of rice farmers.

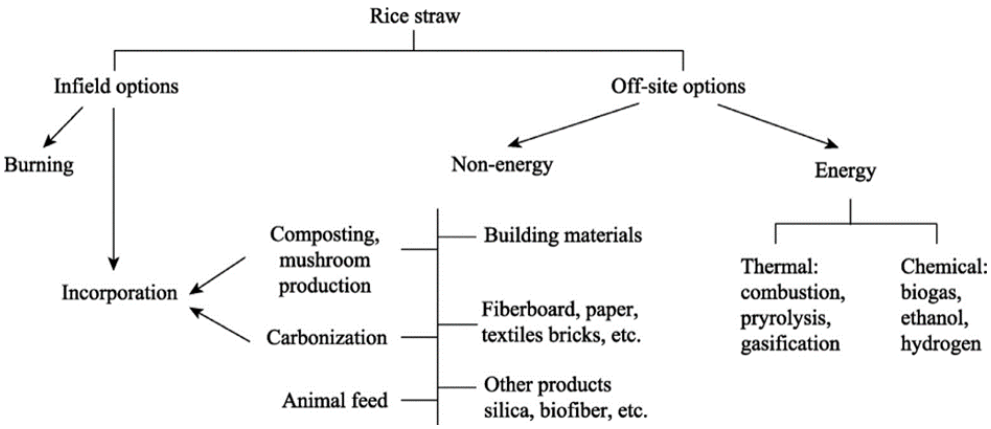

Fig. 2. Summary of leading options for the use of rice straw.
Source: [18]

Application of rice straw in the production of biofuels, as biofuels help reduce greenhouse gas (GHG) emissions, provide energy security across the globe, and advance sustainable development [21]. By maximising the use of straw, as mentioned above, rice farmers can boost income beyond the sale or value of rice grain and promote sustainable development by gaining extra value from the by-products of rice production.

The husk is one of the ways to grind grain, and farmers can use it to add value to their crops, and perhaps raise the income of rice farmers. The husk, which is a dry, scaly covering

that covers the interior of the grain and serves as protection, is a component of the grain. During rice milling, the husks separate from the grains and turn into leftovers or milling trash. Husks typically contribute 20%–30% of the grain's initial weight during rice milling. Husks can be burned or converted into charcoal for planting media, feed combinations, or bedding for cages [18]. In Fig. 3., Goodman [18] shows various uses of rice husks, which can be used to increase rice farmers' added value and income.

According to the International Rice Research Institute (IRRI) [22], processing 100 kg of unhusked rice yields approximately 5-10 kg of rice bran [RI1]. This by-product is a valuable mixture of protein, fat, ash, and crude fibre. It's important to note that bran may sometimes contain small amounts of rice hull fragments, which can elevate its ash content. The exact composition of rice bran depends heavily on the milling process used. Despite its humble origin, rice bran is a powerhouse of nutrients. It is an excellent source of vitamins B and E, along with valuable proteins. Additionally, rice bran contains trace amounts of antioxidants, which are believed to contribute to lower cholesterol levels in humans. Another notable feature of rice bran is its oil content, which ranges from 10 to 23%. This oily nature makes bran an excellent binding agent for animal-feed formulations. Once extracted and stabilised, rice bran oil transforms into a high-quality vegetable oil suitable for cooking or consumption. Traditionally, rice bran has been primarily used in animal feed, particularly for ruminant animals and poultry. However, recent advancements in stabilisation methods have unlocked new possibilities. Rice bran and its derivatives, such as bran oil for cooking and waxes for cosmetics, are finding exciting applications in various sectors.

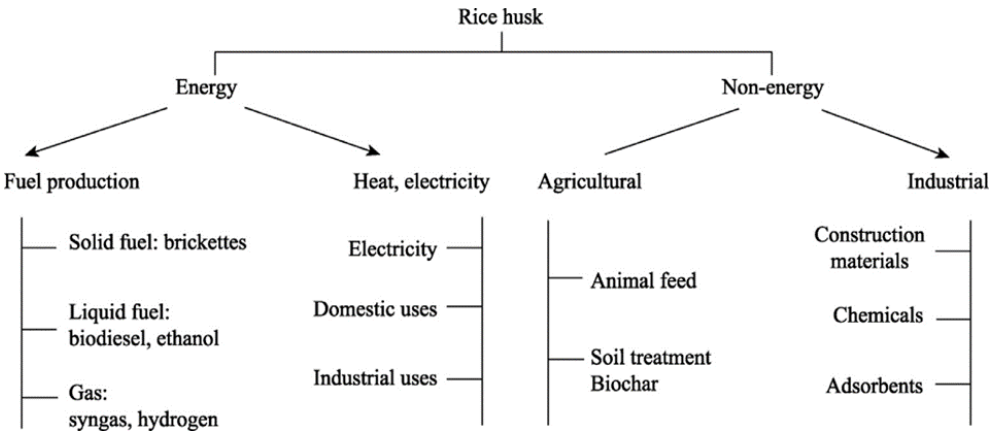

Fig. 3. Summary of leading options for the use of rice husk.
Source: [18]

It is required to create workable stabilisation techniques as well as value-added procedures for the nutrients and active components to increase the usage of rice bran. The primary nutrients in rice bran are oils, proteins, and carbohydrates. Additionally, rice bran is a rich source of bioactive compounds, including phytic acid, non-starch polysaccharides, phenolic acids, flavonoids, tocopherols, and tocotrienols, which contribute to its overall health benefits. Antioxidant and anticancer properties are present in these substances [23]. Based on its rich nutritional content and active composition, rice bran has excellent potential to be used as a source of healthy, functional food.

Research shows that rice bran can also be used to prevent and overcome the problem of stunting [24]. In this case, rice bran supplementation shows promise in improving children's gut health. It delivers essential nutrients, acts as a prebiotic promoting beneficial gut bacteria, and contains phytochemicals that may help reduce harmful gut pathogens and diarrhoea.

These potential benefits warrant further investigation to explore their role in mitigating Environmental Enteric Dysfunction (EED), a condition linked to stunting due to nutrient absorption problems.

Based on the functions and benefits of rice bran, rice farmers need to be encouraged to use rice by-products in the form of rice bran. It is hoped that farmers will gain added value, increase their income, and at the same time contribute to providing functional food that is beneficial for the health of the population and efforts to overcome the problem of stunting in Indonesia.

4 Conclusions and policy recommendations

4.1 Conclusions

An R/C value greater than one indicates that rice farming in Indonesia is financially feasible and profitable. However, with the average land area cultivated by rice farmers being less than 0.3 ha, the income obtained from rice farming is still lower than the UMR. Until now, income generated from rice farming has mainly been calculated based on the main rice products, namely grain and rice. By-products and waste from rice plants in the form of straw, husks, and rice bran have the potential to be processed and utilised to produce added value and increase farmers' income. Using a circular economy approach, processing and utilising straw, husks, and rice bran can increase added value, increase rice farmers' income, support sustainable development, and provide healthy and functional food.

With the number of rice farming households in Indonesia amounting to more than 13 million, increasing the added value and income of farmers from rice farming through the processing and utilisation of by-products and rice plant waste is expected to improve the welfare of some of the rural population.

4.2 Policy recommendations

To efficiently process and utilise by-products and waste from rice plants, farmers must work together and collaborate within farmer groups, farmer corporations, or farmer-owned enterprises. Based on the fact that the average scale of rice farmers' businesses is relatively small, the advantage of economies of scale can be tapped by doing business together, which may create efficient processing and marketing activities.

If there is already a farmer group, then for the processing and utilisation of rice by-products and waste, farmers do not have to form a new group but can become one of the farmer group's business units. For this reason, support, facilitation, and guidance from the regional government and related agencies, especially agriculture, industry, and trade services, are needed. Collaborative partnerships between the industrial sector and rice farmer groups are also required to implement a bio-circular approach for processing and utilising by-products and rice plant waste.

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