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Rice Husk Availability Mapping as Biomass Cofiring Material at Power Plant in Indramayu

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Abstract

Indonesia plans to reduce greenhouse gas (GHG) emissions by 29% by 2030 to address its high fossil energy use. One strategy involves PT PLN (Persero) implementing biomass cofiring technology in 52 power plants by 2025. As the 4th global rice producer, rice husk become a potential source for this strategy in Indonesia. However, sustainability of supply is a challenge, with inadequate research and only 33.52% recording at the rice mills. This study aims to quantify the rice husk availability for biomass cofiring in Indramayu Regency, the Indonesia's largest rice-producing area. Using a spatial approach, surveys, interviews, and Quantum GIS (QGIS) version 3.22.12, a visual map of rice husk availability was created. The result of the research is 95 data of rice mills (79 small, 12 medium, 4 large) which showed daily husk potentials of 0.87, 4.83, and 10.74 tons, respectively. National production data estimated theoretically an annual availability of 272,106 tons of rice husk. Spatial analysis from surveys and interviews indicated 601,669 tons/year, while distribution by milling scale suggested 588,861 tons/year. Competition for rice husk use was high in industries like roof tile, brick, and cement, with recovery fractions (α) of 13.23%, 17.50%, and 23.33% during harvest, and 3.90%, 10%, and 15% in the off-season. With information of operational days from each mill scale during the harvesting and the off-season, the mobilizable of rice husk was calculated as 77,102.17 tons/year. Policies promoting the use and management of rice husk in rice-producing areas are necessary to enhance biomass cofiring implementation.

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1. Introduction

Nationally, fossil energy (oil and gas) dominates at 91% (IESR 2021), challenging Indonesia's goal of achieving a 23% renewable energy mix by 2025 and reducing greenhouse gas (GHG) emissions by 29% by 2030. By the end of 2019, renewable energy implementation reached only 9.15%, with 6.2% from EBT plants and 2.95% from biofuels (BPPT 2021). Biomass is a key renewable source, but only

5.6% of its potential has been utilized, equating to 1,889.8 MW (KESDM 2020). Indonesia initiated biomass cofiring technology at PT PLN in early 2020, implementing it in 32 locations, 63% of the 2025 target, generating up to 487 MWh of green energy (DMPEBT 2022). Biomass cofiring substitutes coal with biomass fuel, yet maintaining biomass supply sustainably is a major challenge, especially without exceeding generation costs (DJEBTKE 2021). PLN uses biomass materials like sawdust, wood chips, corn cobs, rice husks, and SRF. Rice husk is promising given Indonesia’s position as the fourth largest rice producer, but availability information is insufficient. BPS (2021) indicates 66.48% of rice mills lack production records, necessitating research into rice husk's biomass potential for cofiring.

Studies by Dewi and Ardhitama (2020) and Sudia et al. (2020) show rice husk potentials of 3,274 GJ/year and 1,700 GJ/year, respectively, but lack comprehensive utilization data. This research focuses on mapping rice husk availability using geographical information systems (GIS) to visualize potential, specifically by employing the Quantum GIS (QGIS). This is a part of the spatial data analysis which is crucial for identifying the distribution of rice husk availability. This research will be conducted in Indramayu Regency, West Java Province, the largest rice-producing area in Indonesia and home to an operational biomass cofiring power plant. The study aims to provide detailed data on rice husk availability in the form of a map.

The spatial analysis on rice husk availability will produce a map with abundance in each sub-district in Indramayu. The visual of the map is expected to ensure an alternative reaching a sustainable supply for biomass cofiring. Furthermore, the findings will aid in aligning national renewable energy targets with local biomass resources, contributing to Indonesia's overall strategy for reducing GHG emissions and increasing the renewable energy mix.

2. Materials and Methods

This research was conducted from August 2022 to January 2023 in Indramayu Regency and the Bioinformatics Engineering Laboratory, IPB University. Indramayu spans 2,099.42 km² with 31 sub-districts and 317 villages (BPS 2023). The administrative map of Indramayu Regency (Figure 1) illustrates the sampling locations. The region's extensive rice production makes it a significant area for studying biomass availability.

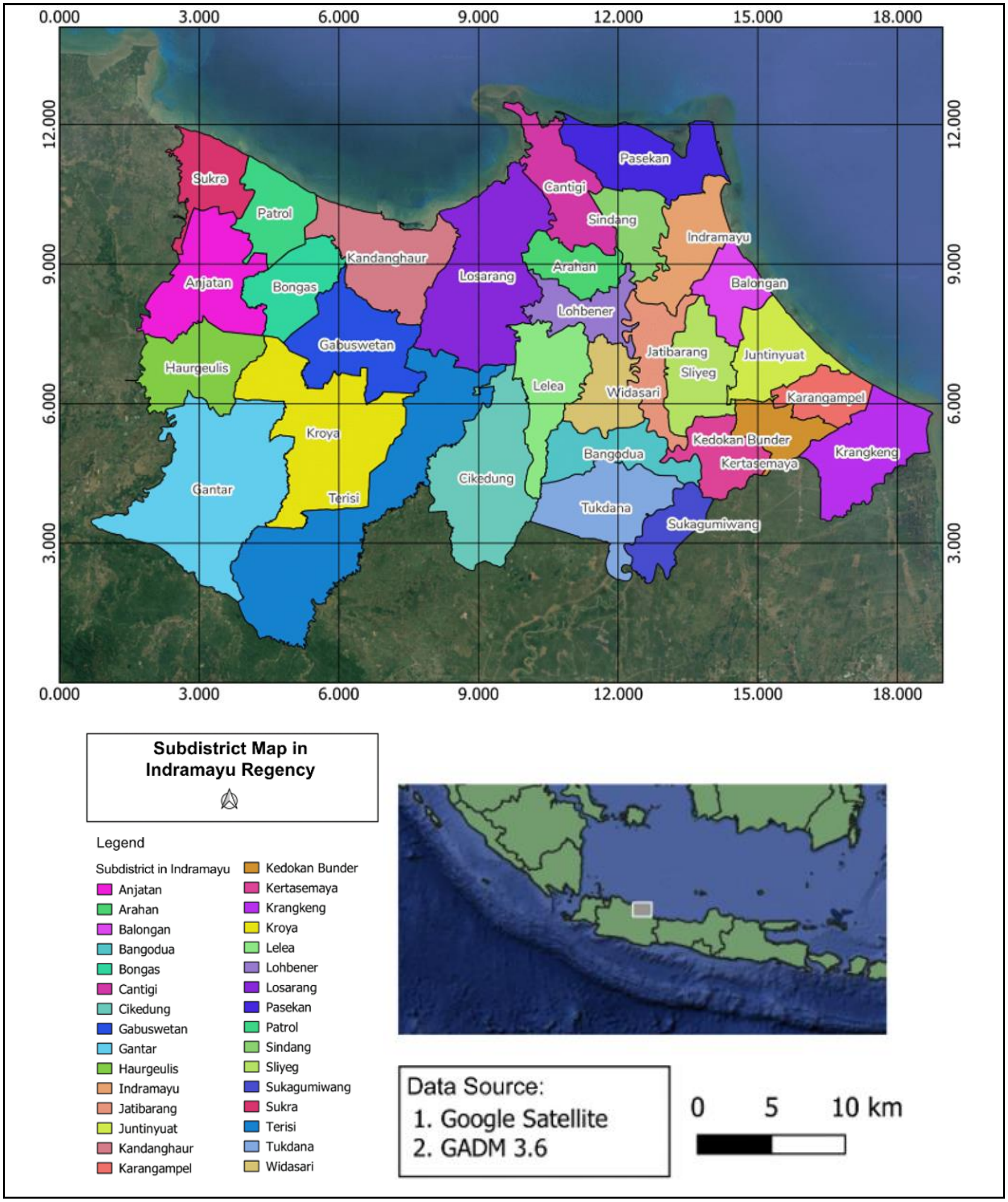


Figure 1. Indramayu Regency map as the survey location

2.1 Types of Data and Tools

Data for this study includes primary data from field observations and secondary data from government and spatial data provider websites. Primary data were in tabular form, while secondary data were in vector form and satellite images (Table 1). Tools and software used include Google Map, Locus, QGIS 3.22.12, a camera, and Microsoft Excel (Table 2). These tools facilitated the accurate collection and analysis of spatial and economic data critical for assessing biomass availability.

Table 1. Research Data and Sources

	Data Type	Source
1	Data on rice mills	BPS West Java
2	Rice mill coordinates	Field survey
3	Biomass availability	Field survey
4	Price and processing cost	Field survey
5	Rice mill distribution map	Indonesia Geospatial
6	Vector BIG administration map	Geospatial Information Agency
7	Rice field map	Ministry of Agriculture

Table 2. Tools and Sofware Used

No	Tools and Software	Usage
1	Google Map	Validate coordinate points from Locus
2	Locus	Marking the coordinates of the rice mill
3	QGIS 3.22.12	Spatially analyzing and creating distribution maps
4	Camera	Documentation of survey locations
5	Microsoft Excel	Processing secondary data and survey results

2.1.1 Research Procedure

This research analyzes rice husk availability in the Indramayu Regency using spatial data from rice mill coordinates. QGIS 3.22.12 was used for spatial analysis, supplemented by field surveys and interviews with rice mill managers. The combination of these methods ensures a comprehensive understanding of the biomass landscape in the region.

1. Literature Study

The literature study explored existing research on rice husk availability and spatial distribution, aiming to understand the background and necessity for this research. This stage provided a foundation by highlighting gaps in current knowledge and identifying the potential for rice husk utilization in biomass cofiring. There are two main equations that will be used for the calculation of energy (E) of power plants (Stein 2024) and mass of biomass (Barry et al. 2022).

$$E = P \times t / \eta \tag{1}$$

where E is the power plant energy (GJ), P is power plant capacity (MW), t is time (second), and η is power plant efficiency.

$$M = E / LHV \tag{2}$$

where M is the mass of biomass (ton), E is biomass energy (GJ), and LHV is the lower heating value of the rice husk.

2. Primary Data Collection

Field surveys and interviews were conducted to collect primary data, including location coordinates, husk prices, and factors affecting prices such as transportation modes. This data is essential for evaluating the economic viability of biomass usage.

a. Determination of Primary Data Feasibility

Coordinates, prices, and transportation details were collected using Locus and Google Maps. According to DMPEBT (2022), the feasibility of biomass use was assessed based on three cost components: biomass feedstock, biomass processing, and transportation. All rice mills in Indramayu fall within the feasible distance for biomass supply, ensuring a practical implementation for biomass cofiring.

b. Sample Size Determination

Using the Slovin formula with a 10% error margin, 95 rice mills were surveyed from a population of 1,616. The sample included 79 small, 12 medium, and 4 large-scale mills, ensuring a representative cross-section of the industry.

$$n = N/(1+N (e^2)) \tag{3}$$

where n is the number of samples, N is the total population, and e is the percent error value.

c. Secondary Data Collection

d. Secondary data included distribution maps from BPS and the Ministry of Agriculture and administrative data from the Geospatial Information Agency. This data provided additional context and supported the primary data analysis.

3. Data Processing

Data processing involved digitizing coordinates, weighting sample data, processing attribute data, and uploading this data to QGIS for spatial distribution analysis.

a. Coordinate Digitization

Coordinate data collected via Locus and Google Maps were compiled in Microsoft Excel.

b. Weighting and determining reference data

Sample data were weighted to match the population distribution of rice mills, ensuring proportional representation.

c. Processing of Attribute Data

Qualitative data from interviews were added to Excel for analyzing rice husk availability across different milling scales.

d. Attribute Data Upload

Processed attribute data were saved in csv format and uploaded to QGIS for spatial analysis of rice husk distribution and proceeded with map creation.

4. Risk Husk Availability Analysis

The availability of rice husk was analyzed using theoretical and mobilizable potential, adapted from Barry et al. (2022), as shown in Figure 2. This research employs the approach to calculate the theoretical and mobilizable availability of the rice husk.

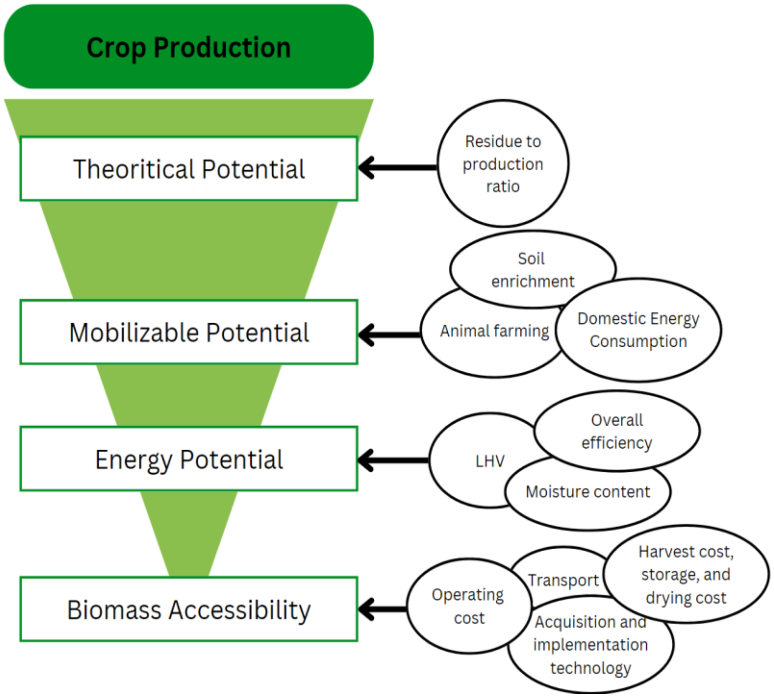


Figure 2. Assessment level of agricultural biomass availability according to Barry *et al.* (2022)

a. Theoretical Availability

Theoretical availability was calculated using the residue-to-production (RRP) ratio. The potential biomass (Qt) was estimated from annual rice production and the RRP value of 20% (Dhankar 2014; NRR 2016; IRRI 2016).

$$Qt = Pi * RRP \tag{4}$$

where: Qt (tons) is the theoretical potential quantity of rice production residues in milled dry grain (GKG), Pi (tons) is the annual production of Indonesian rice commodity, and RRP is the ratio of residue to rice production in mass units of GKG.

b. Mobilizable Availability

Mobilizable potential was calculated by subtracting existing uses of rice husk from the theoretical potential, using recovery fractions based on field surveys. This determined the quantity of rice husk available for biomass cofiring. The amount of rice husk biomass that can be mobilized (Qm) was calculated by applying the following Equation (5).

$$Qm = Qt * \alpha \tag{5}$$

where Qm (tons) is the quantity of potential residue that can be mobilized, Qt (tons) is the theoretical residue potential amount of rice husk, and α is the recovery fraction based on some assumptions of residue utilization.

Recovery fraction values have been determined by previous researchers such as fraction values of 10-25% according to OECD and IEA (2010) and variations of 10%, 25%, and 40% at low, medium, and high levels respectively according to Kemausuor et al. (2014). In this study, the recovery fraction will be determined based on field surveys and the real fraction that exists in rice mills in Indramayu on average across all rice mills found.

3 Result and Discussion

Rice milling is a crucial part of the grain-to-rice processing supply chain, involving farmers, collectors, and rice mills. Most rice mills in Indramayu follow a chain that starts with farmers and moves through collectors, rice processing industries, wholesalers, retailers, and finally to consumers. According to BPS (2021), rice mills serve as a pivotal point for production, processing, and marketing. The processing of rice husk, a by-product of rice milling, depends heavily on the milling process itself. Figure 3 outlines the post-harvest rice processes and products up to the rice mill, adapted from Salsabilla et al. (2014), Sudia et al. (2020), and BPS (2022), with a 20% multiplier used for estimating rice husk potential.

Indramayu Regency has 1,616 rice mills: 1,340 small-scale, 207 medium-scale, and 69 large-scale. This number has decreased from 1,786 mills in 2012, indicating a reduction in rice availability as fewer mills suggest less rice production (BPS 2021). The competition for raw materials among many mills can increase prices (Firdaus 2018). Adjusting the number of mills to match production capacity is crucial for maintaining competitive grain prices.

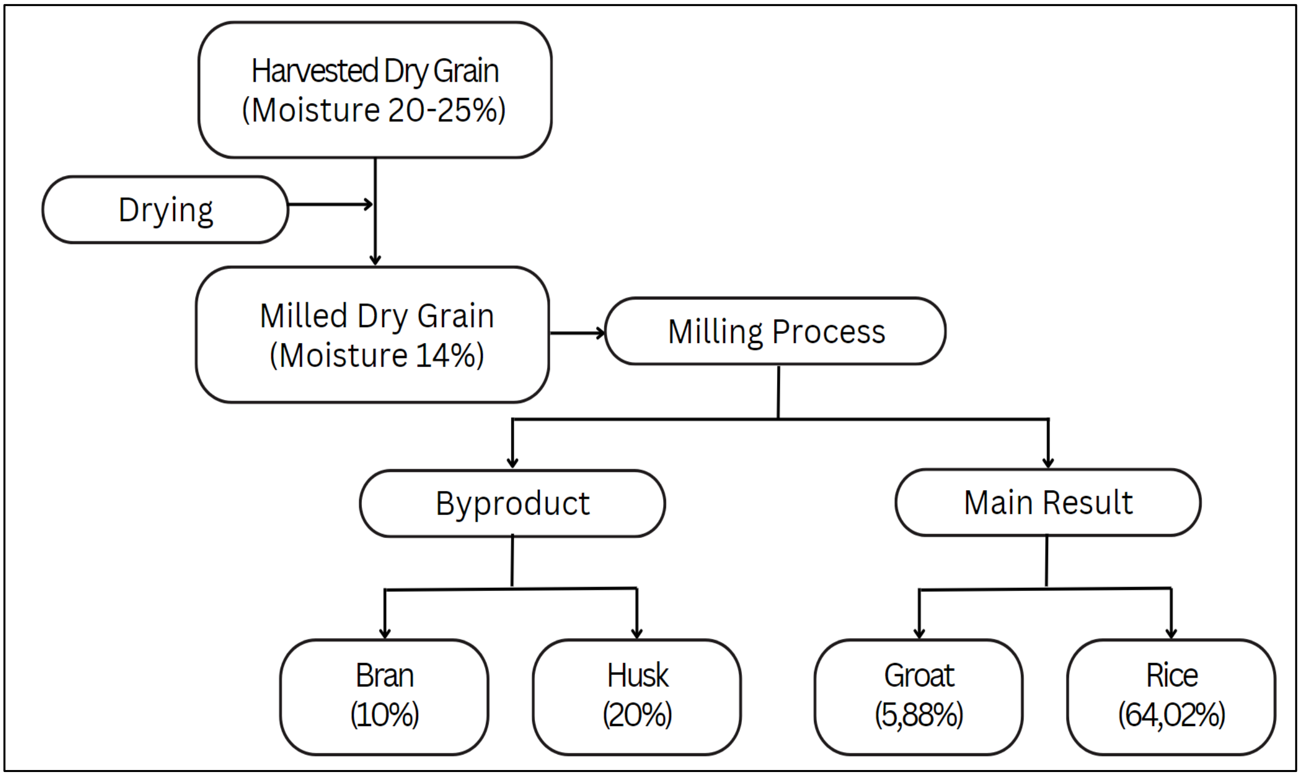


Figure 3. Rice Postharvest Process and product flow

The Indonesian Rice and Grain Millers Association (PERPADI) has proposed scenarios for the ideal number of rice mills. PERPADI (2014) suggests reducing the number of small-scale mills to balance grain production, thereby reducing competition for raw materials. Rachmat (2012) proposed an integrated milling model to enhance value by improving rice quality and yield. Figure 4 shows changes in the number of rice mills between 2012 and 2020 across Indramayu's sub-districts. Some sub-districts saw increases in mills, likely due to expanded harvest areas, as detailed in Appendix 1. This appendix, based on BPS data, shows that increased harvest areas in six sub-districts correspond with more rice mills, though Lelea sub-district had stable harvest areas but increased milling demand possibly due to nearby high-yield areas like Cikedung.

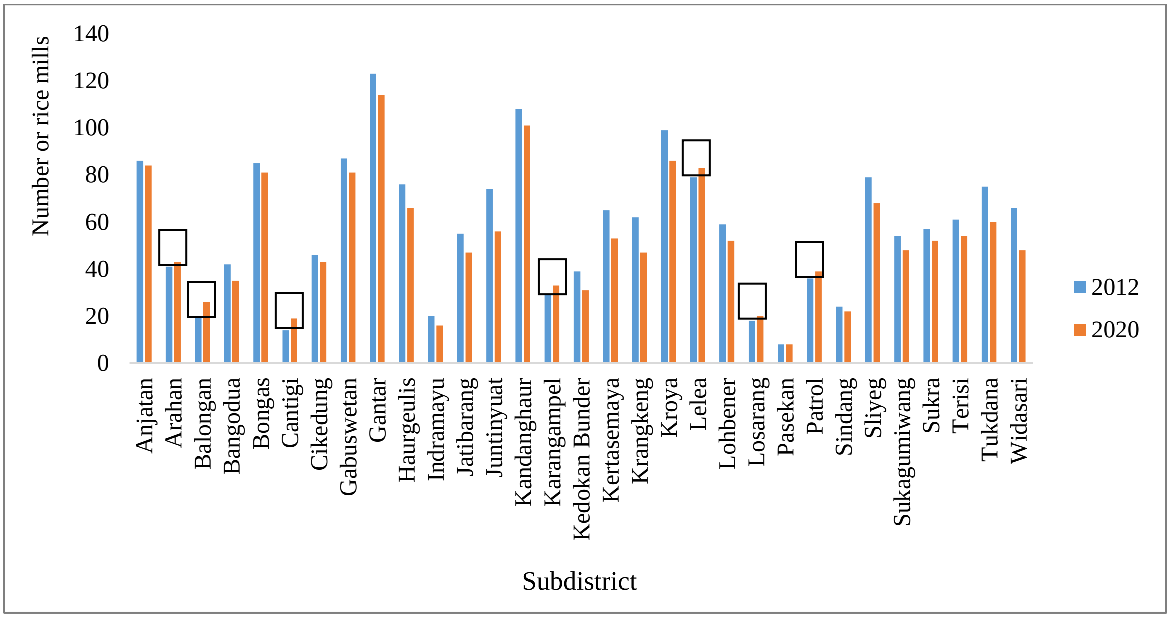


Figure 4. Development of the number of rice mills in 2012 and 2020

3.1 Rice Milling Operations

Rice mills in Indramayu typically operate four days a week: small mills four days, medium mills five days, and large mills six days. They do not operate on public holidays. The production duration affects the estimation of rice husk potential, as daily production capacities accumulate over the year. Harvest periods in Indramayu are around April and October, with non-harvest periods in the remaining months. Table 3 details annual production days for different mill scales, which are used to estimate husk potential during harvest and non-harvest periods.

Table 3. Calculation of rice milling production days in one year

Mill scale	Harvest period (days)	Non-harvest period (days)
Small	52	40
Medium	60	200
Large	60	240

Production recording is essential for estimating rice mill performance and determining rice husk potential. However, 66.48% of rice mills in Indonesia do not keep production records (BPS 2021), making it difficult to monitor production trends. All small-scale mills lack records, often due to the unpredictability of grain milling. In contrast, most medium and large-scale mills maintain production records about 84.21% and 100% respectively. Efficient mills can thrive, while small mills struggle, highlighting the need for government intervention. PERPADI (2022) suggests a revitalization program for small mills focusing on technology, institutions, and financing to ensure the sustainability of the rice processing industry. This program aims to provide capital assistance, facilities, and support for small-scale mills to enhance their competitiveness and efficiency.

3.2 Availability based on overall sample data

The quantity of husk was calculated using the rice mill locations in Indramayu, where the husk supply originates. Calculating husk based solely on GKG rice production from local fields is inadequate, as rice mills process rice from various regions, not just Indramayu. Figure 5 shows the map of the 95 sample locations from the field survey, with coordinates of each mill and sub-district boundaries in Indramayu Regency.

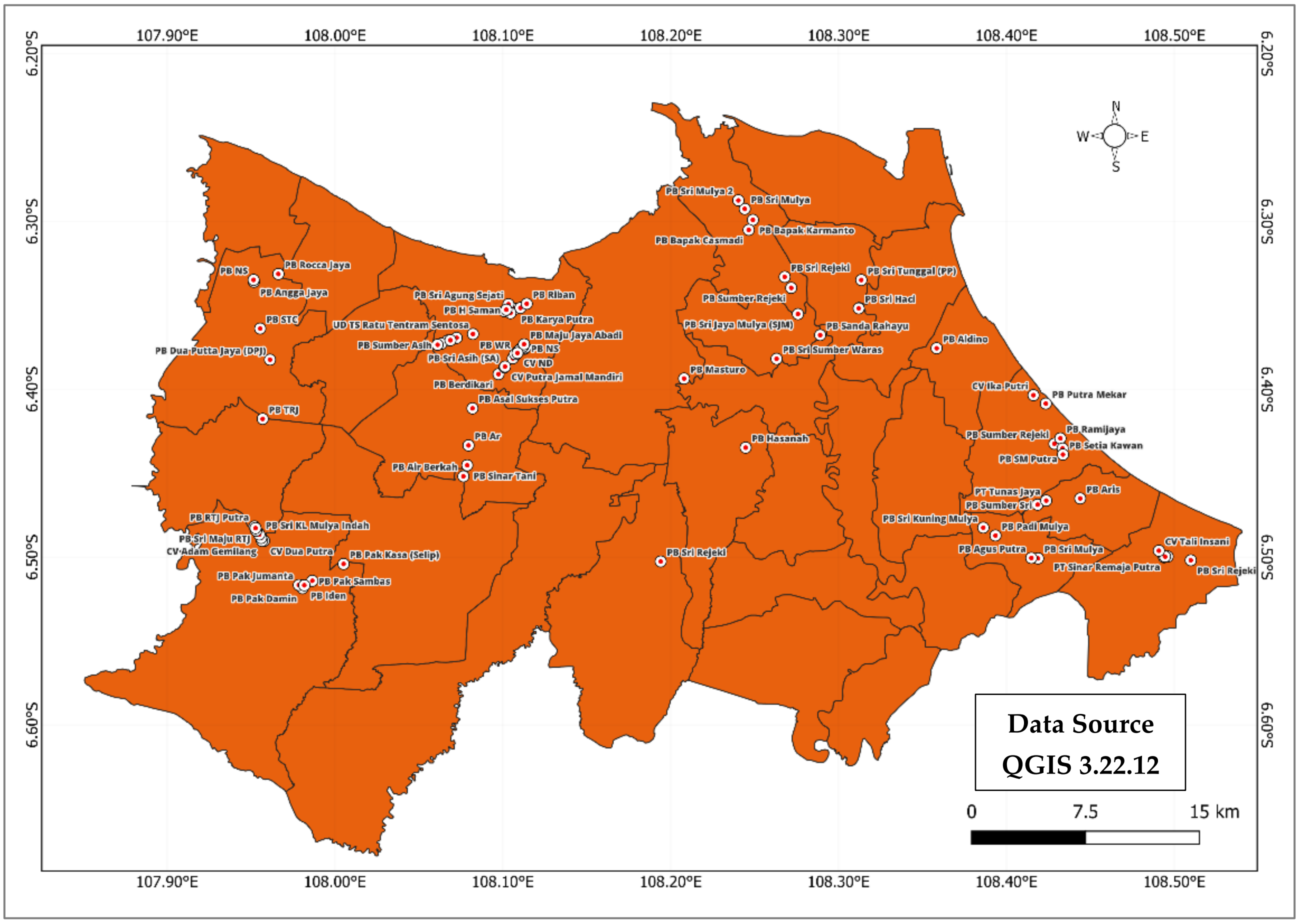


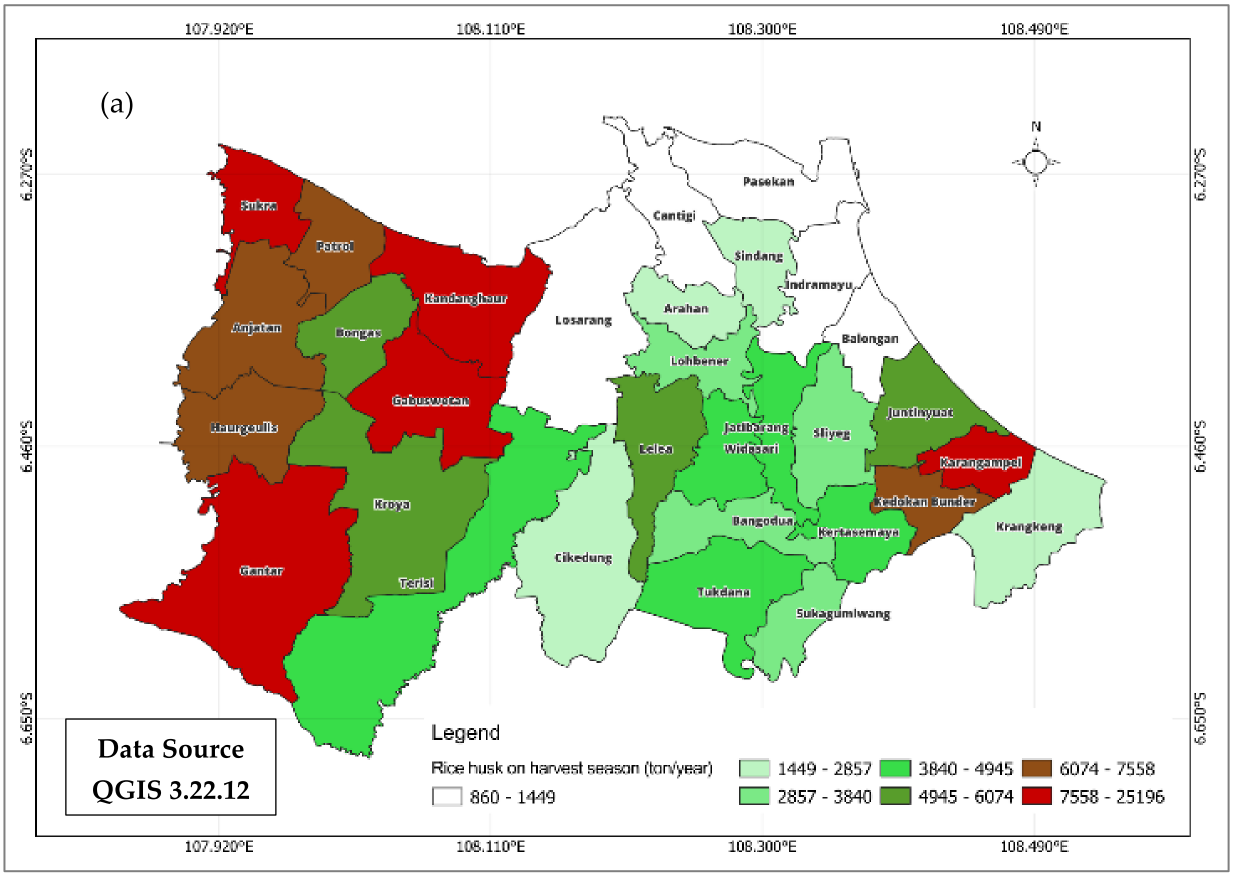
Figure 5. Map of 95 rice mill locations in Indramayu

The average rice production at Indramayu mills is 5.72 tons/day, generating a potential of 2,894 tons/day or 601,669 tons/year of rice husk. This surpasses the 272,106 tons/year potential calculated solely from Indramayu's rice production, as mills source paddy from across Central Java, West Java, East Java, and Banten provinces. Therefore, accurate husk availability estimates should be based on actual mill yields rather than just regional production data multiplied by the husk fraction.

3.3 Availability Based on Production Scale

Based on the sample data, the total number of small-scale, medium-scale, and large-scale rice mills is 79, 12, and 4, respectively, according to the weighting calculation. The average daily rice production capacity at each scale is 2.79 tons/day, 15.5 tons/day, and 34.4 tons/day. These values indicate rice husk availability during harvest and non-harvest periods at 165,075 tons and 423,786 tons, respectively, with a total annual availability of 588,861 tons/year. This estimates the rice husk potential in an area if the number of rice mills at each scale is known.

The spatial distribution of rice husk is shown in Figure 6, with availability during harvest and non-harvest periods. Kandanghaur sub-district has the highest availability, with 25,196.17 tons/year during harvest and 88,063.13 tons/year during non-harvest periods. This high potential is due to the concentration of medium and large mills and the large rice harvest area in nearby sub-districts with fewer mills. In contrast, Losarang sub-district has fewer rice mills but a larger harvest area, leading to a significant husk potential.



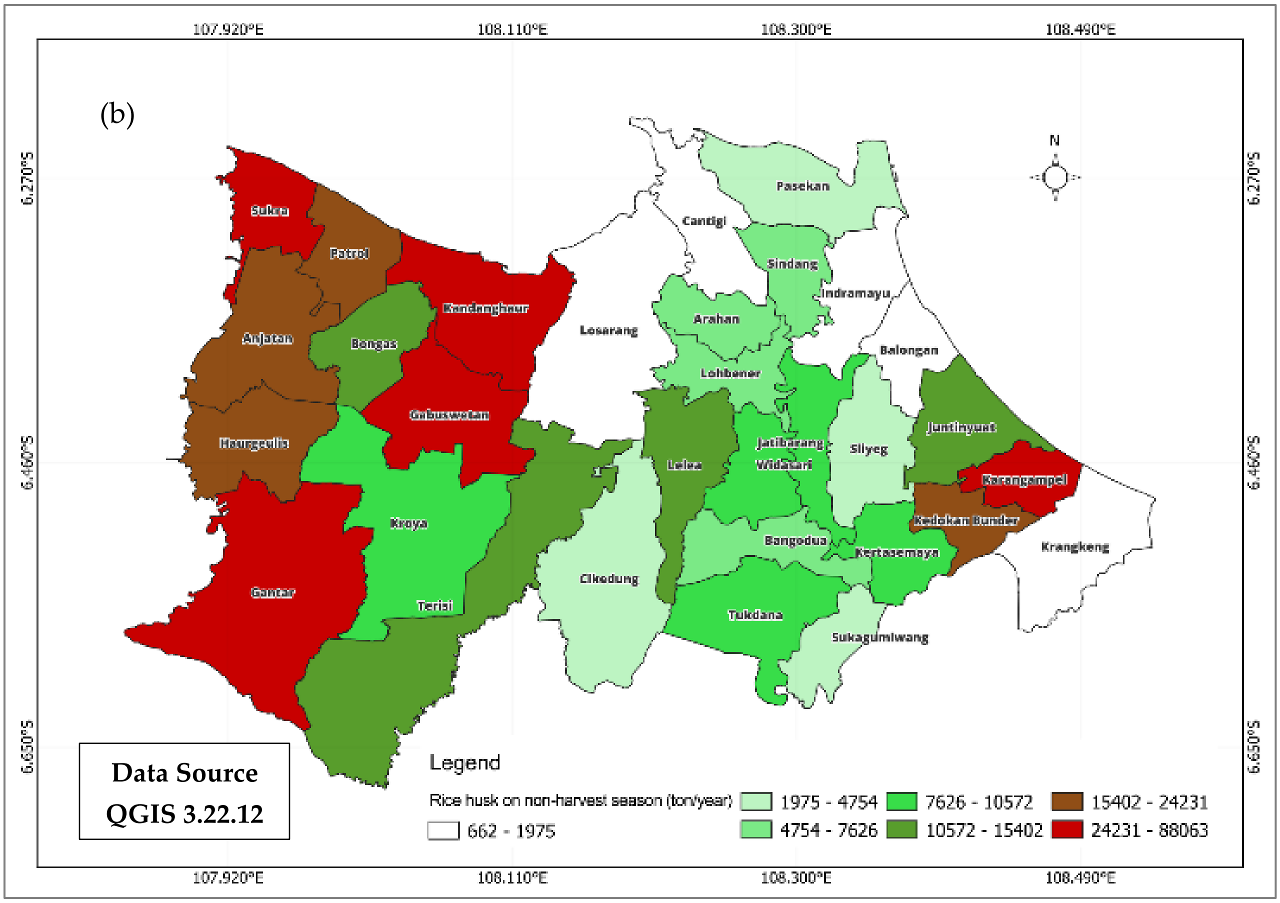


Figure 6. Rice husk availability during (a), harvest season and (b) non-harvest season

Farmers prefer medium and large-scale mills for better rice quality, influencing husk availability in these mills (Ulfa et al. 2014; Ma'arif 2016). The least amount of potential husk is found in Cantigi sub-district, with 860.13 tons/year during harvest and 661.64 tons/year during non-harvest periods. This is due to the dominance of small-scale mills and consumer preference for higher-quality milling. Small rice mills, operating with limited capacity and older machinery, produce lower-quality rice (Alfi, 2017).

3.4 Rice husk utilization and competition

The calculation of rice husk usage aims to determine how much the availability of rice husk as biomass cofiring material is reduced. In Indramayu, rice husk utilization is distributed among eight uses based on interviews with rice mill managers. Figure 7 shows that the largest portion of rice husk is used as fuel for the brick and tile industry, while the smallest portion is used as home fuel. Generally, rice husk is used as fuel (for the brick, tile, and cement industries), planting media, and domestic purposes (road, cage, and home fuel). Barry et al. (2022) note that the sustainability potential of biomass waste as an energy source is influenced by the density and competition for its use in an area.

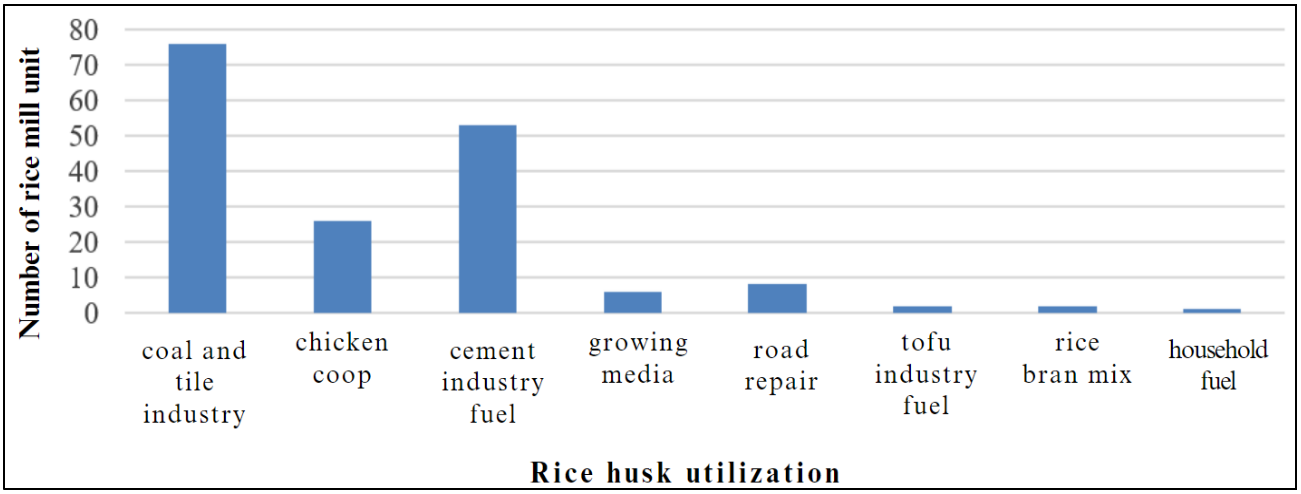


Figure 7. Distribution of rice husk use in Indramayu

Determining the competition for use aims to identify the recovery fraction (α) as a multiplier for chaff availability in potential estimations. Each milling scale categorises The recovery fraction by harvest and non-harvest periods (Table 4). According to Kemausuor et al. (2014), the recovery fraction is classified into low (10%), medium (25%), and high (40%) levels. This study classified the recovery fraction as very low, low, and medium, with the lowest fraction in small-scale mills during the non-harvest season and the highest in large-scale mills during the harvest season. Many rice mills have stockpiled husks needing transport, especially during harvest or large events. This unutilized potential can be redirected to sectors needing biomass, such as biomass cofiring feedstock in power plants.

Table 4. Average recovery fraction (α) at each milling scale

Mill scale	Harvest Period	Non-Harvest Period
Small	13,23%	3,90%
Medium	17,50%	10%
Large	23,33%	15%

3.5 Mobilizable rice husk availability

The recovery fraction from husk use competition data is applied to previous husk availability to estimate mobilizable rice husk. Spatial analysis (Figure 8) shows the highest potential in Kandanghaur sub-district (16,929.48 tons/year) and the lowest in Cantigi sub-district (173.34 tons/year).

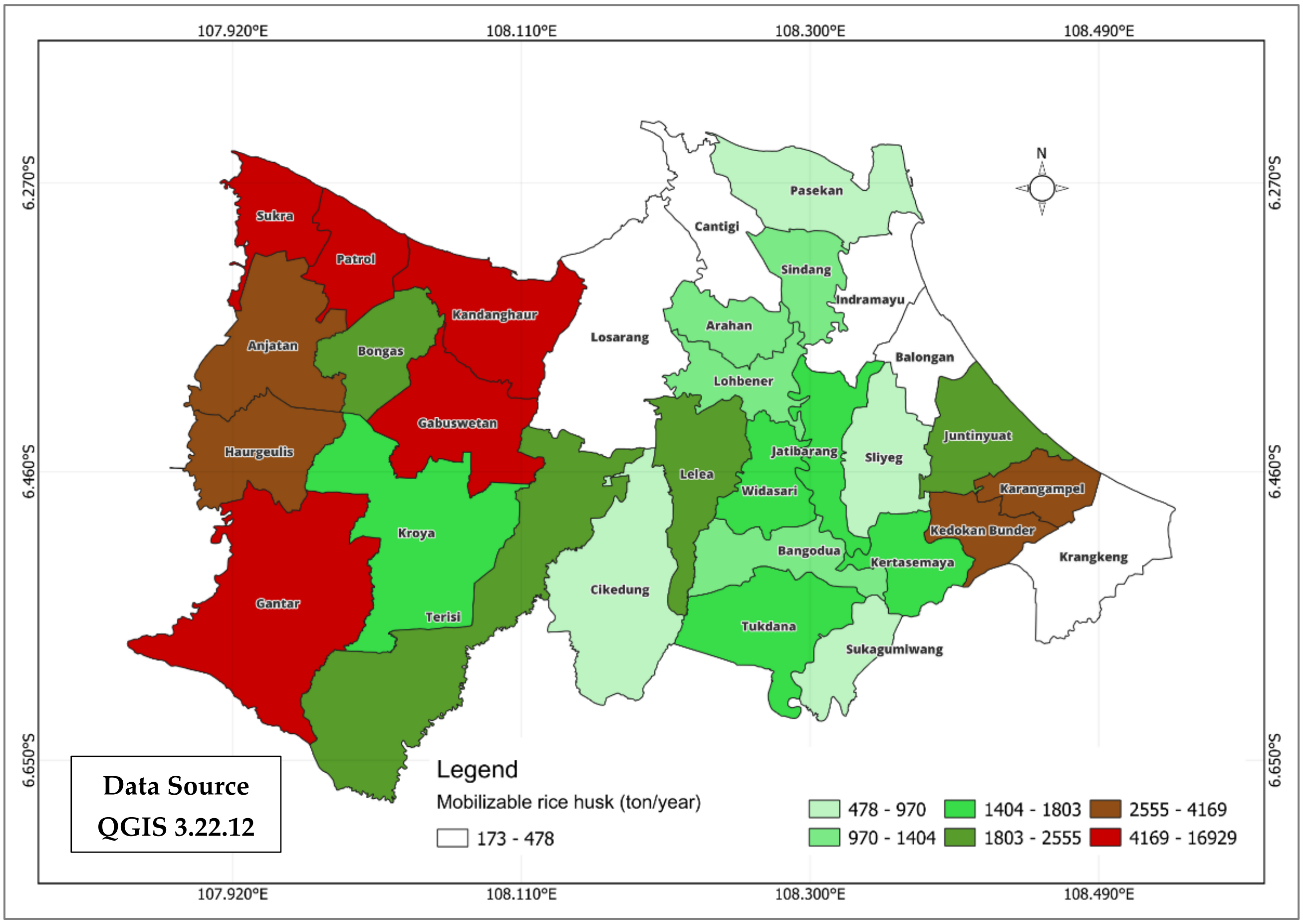


Figure 8. Availability of rice husks that can be mobilized

Sub-districts with low husk potential often mill rice in areas with higher potential due to rice quality preferences. Sub-districts such as Losarang, Cantigi, Indramayu, Balongan, and Krangkeng likely mill rice in Kedokan Bunder, Karangampel, and other high-potential areas. Significant husk quantities are found in western Indramayu (e.g., Kandanghaur, Sukra, Gabuswetan) and eastern Indramayu (e.g., Karangampel, Kedokan Bunder). These areas are ideal for supplying rice husk biomass for the Indramayu PLTU.

The total mobilizable rice husk in Indramayu is 77,102.17 tons/year. Utilizing rice husk as biomass is economical and reduces deforestation and biodiversity loss compared to using energy crop forests (*hutan tanaman energi* - HTE) for wood-based bioenergy. Muamar (2022) highlights the risks of using HTE-supplied wood pellets, including supply chain issues and increased greenhouse gas emissions. Effective energy conversion considers technology, production costs, raw material availability, and environmental impact. The rice husk availability data from this research can be an alternative biomass supply for cofiring. Government policies promoting rice husks for cofiring can enhance supply chain sustainability and add value to rice husks, benefiting rice-producing regions across Indonesia.

4. Conclusion

Rice husk availability is determined by data on rice mills, including the number and scale of mills, operating hours, and daily rice production during harvest and non-harvest periods. This study surveyed 95 mills: 79 small, 12 medium, and 4 large, operating 4, 5, and 6 days, respectively. The husk potential per day is 0.87 tons for small, 4.83 tons for medium, and 10.74 tons for large mills. Indramayu's husk availability was identified as 272,106 tons/year based on national production data, 601,669 tons/year from surveys, and 588,861 tons/year based on milling scale distribution.

Rice husk in Indramayu is used in eight ways, primarily as fuel for the roof tile, brick, and cement industries. The recovery fraction (α) for husk is 13.23% for small, 17.50% for medium, and 23.33% for large mills during harvest, and 3.90%, 10%, and 15% respectively in the non-harvest season. Mobilizable husk availability is 77,102.17 tons/year, suitable for biomass cofiring at the Indramayu PLTU. Policies promoting rice husk utilization could enhance supply and add value to the rice mill supply chain, benefiting mill managers and local communities.

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