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Potential decline in domestic rice production due to the degradation of land functions from paddy fields to other uses: A case study in Banyumas Regency, Central Java, Indonesia

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ABSTRACT
Access to food is a human right. Rice is the staple food for almost all Indonesians and is a basic human need, so the state is obliged to guarantee its availability and affordability evenly throughout the region. The destruction of paddy fields due to changes in use in various regions in Indonesia affects the national food supply. The contribution of domestic rice is decreasing, and the dependence on imported rice is increasing. In the long term, this phenomenon will threaten efforts to fulfill the adequacy of the staple food rice for the growing population, thereby increasing the potential for a food crisis. This study analyses the decline in domestic rice sufficiency due to the destruction of paddy fields in Banyumas Regency, Central Java Province. The method used in this study is mixed, consisting of visual image interpretation, map overlay, and descriptive quantitative analysis. The results showed that the average rate of destruction of paddy fields in Banyumas Regency from 2007 to 2019 was 102.6 hectares per year, concentrated around Purwokerto District, which is the capital of Banyumas Regency. The potential loss of rice production is 1,189,580 kilograms per year of harvested dry grain, equivalent to IDR 5,709,984,000.00.

Keywords: Cropping index; overlaying; self-sufficiency; SPOT image; visual interpretation .

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INTRODUCTION
Rice is a staple food for most of the population of countries in the Asian region. Access to food is a human right; therefore, the state must ensure its availability, affordability, and equal distribution of sufficient and quality food consumption evenly throughout the region. As stated in the SDGs, one of the goals of sustainable development is to end hunger, achieve food security and better nutrition, and promote sustainable agriculture (World Health Organization 2015). Thus, promoting sustainable agriculture is a strategic agenda in development programs. Apart from providing food for the population, agriculture also plays a role in absorbing labour, contributing to gross domestic product (GDP), stabilizing inflation (Majidah et al. 2021), generating foreign exchange (Kusumaningrum 2019), and a source of raw material for industries (Sari and Bangun 2019).

The Indonesia government has implemented various policies to meet the staple food needs of rice for its population. Their policies include improving farming technology (intensification), creating new paddy fields (extensification), food diversification campaigns, and controlling agricultural land degradation through various programs and policies. Indonesia's success in implementing the green revolution movement encouraged the achievement of rice self-sufficiency in 1984. The program was characterized by increased high-input technology in paddy fields through an intensification program to boost rice production. However, the program caused several negative impacts, including soil saturation with fertilizer inputs.

Land degradation is a problem that occurs in all parts of the world. Land degradation is extensive, covering about 23% of the world's land area, increasing at an annual rate of 5 to 10 million ha, and affecting about 1.5 billion people worldwide (Stavi and Lal 2015). For this reason, one of the SDGs targets in goal 15 requires that ongoing or existing land degradation be offset by restoration, rehabilitation, and sustainable land management either on-site or off-site. Maintaining

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terrestrial ecosystems in the SDGs can be interpreted as an agenda to protect the amount and quality of land resources needed to support ecosystem functions and improve food security globally by 2030 to meet the needs of one generation to the next.

Land degradation is when the quantity and quality of land decrease at spatial, temporal and ecosystem-specific scales. Land degradation can also be considered as a reduction in ecosystem services. Land degradation involves a reduction in future biological productivity and a decrease in the capacity of land ecosystems to generate benefits from specific land uses under specific forms of land management (Grainger 2015). It includes decreased quality and quantity, leading to a partial or complete loss of land ecosystem functions. In general, land degradation can be divided into two categories: land degradation in quality and land degradation in quantity.

Zero Net Land Degradation (ZNLD) or Land Degradation Neutrality (LDN) is a concept coined in 2011 by the president of the United Nations Convention that includes two complementary mechanisms, namely: 1) managing currently non-degraded land in ways that do not cause degradation, thereby halting further land loss, and 2) at the same time, restoring land that is already degraded (UNCCD 2011). LDN is a global agenda that aims to increase the sustainable protection of ecosystems and biodiversity and stabilize productive land globally. This phenomenon has attracted attention as many countries are experiencing huge losses of agricultural land due to land conversion due to rapid urbanization and expansion of urban areas (Okpara et al. 2018).

Population growth and economic growth will increase the demand for food and energy, dramatically increasing pressure on land (Stavi and Lal 2015). Human activities in fulfilling their needs have made some agricultural land no longer able to function by its designation and even change its function so that in terms of land quantity, there is a decrease. This land degradation is sometimes considered a consequence of development and economic growth. In some areas in Indonesia, there has been a change in function from irrigated paddy fields to built-up land. This incident not only eliminates the function of paddy fields as productive land a producer of rice but often also causes the surrounding irrigation system to be disrupted. This condition will cause the land's carrying capacity in the region to decline. As a result, the production of the staple food rice will decrease. The contribution of domestic rice supply to the national rice availability will decrease, and subsequently, rice imports will increase.

Until recently, the government's policy of importing rice was carried out to ensure the stability of national rice availability, as domestic rice production often fluctuates due to uncertain climatic conditions. However, if the dependence on imported rice increases, the risk of rice stock disruption will arise when the global rice supply is disrupted. Some of the problems related to rice production in various countries are population pressure (Chen 2007), poor plant growth, unsuitable land conditions, inefficient cultivation techniques (Dengiz 2013), and environmental pressures due to climate change (McKenzie and Williams 2015). Besides creating dependence on other countries, the import policy will also result in a fall in the retail price of rice at the farm level due to the increased amount of imported rice in the market. (Purbiyanti et al. 2017; Kusumah 2019). Therefore, efforts to maintain and increase the domestic rice supply are crucial in reducing dependence on other countries (Ruiz 2016; Clapp 2017), but this is quite a challenge (Chaifetz and Jagger 2014).

An important problem in sustainable agricultural development is shrinking agricultural land, especially paddy fields (Widayati 2015; Ambarwulan 2017). Paddy fields are more easily converted than dry land (Ambarwulan 2017; Murdaningsih et al. 2017; Nuraeni et al. 2017). Protecting the existence of paddy fields is a strategic step in preventing the degradation of paddy fields due to urban pressure and regional development. Regulations, such as the Regional Spatial Plan in each district, do not explicitly protect the conversion of paddy fields, so the conversion of paddy fields continues. During the period 2000 to 2015 in West Java, East Java, Bali, West Nusa Tenggara, South Sulawesi, South Kalimantan, South Sumatra, North Sumatra and Gorontalo, it is estimated that paddy fields have been lost at a rate of 96,512 ha.year^{-1} (Mulyani et al. 2016).

Paddy fields are a very strategic ecosystem because they produce staple food for most of the Indonesian population. The main challenges in food provision include the availability of land, which is increasingly scarce both in quantity and quality the destruction of the function of paddy fields, which continues to occur. Damage to the function of paddy fields due to conversion into built-up land will make it more difficult to achieve food self-sufficiency. Food self-sufficiency reflects the ability to fulfil basic food needs independently. The global food crisis and malnutrition problems are increasing due to several factors, including population growth, increasing energy consumption in the agricultural sector, increasing demand for biofuels, and changes in pattern consumption (Shcherbakova and Shcherbakov 2018).

This condition raises concerns that paddy fields will increasingly lose their function as rice producers while the program to create new paddy fields is constrained by limited land and infrastructure. The decline in the adequacy of the staple food rice will be even greater as the destruction of the function of paddy fields continues. In terms of national food supply, the destruction of the function of paddy fields in each district is a serious threat because the impact is permanent and cumulative. This condition will cause national food stability to be disrupted.

Banyumas Regency, with its capital in Purwokerto, is not only the center of activity in the southern part of Central Java, but also the availability of various community service needs, such as education, health and various types of tourism, making this area prone to conversion of paddy fields. Therefore, this study was conducted to analyze the decline in the level of rice sufficiency due to the conversion of paddy fields with a case study in Banyumas Regency, Central Java. This research is expected to be used as a reference to formulate measures to protect the existence and function of paddy fields so that the domestic rice supply can be

maintained and the potential for food insecurity in the future can be minimized.

MATERIALS AND METHODS

Study Site

The research was conducted in Banyumas Regency, Central Java, Indonesia. The study area is part of the southern slope of Mount Slamet. Geographically, it is situated between east longitude 108°39'17" to 109°27'15" and south latitude 7°15'05" to 7°30'10" (Figure 1).

In addition, the area based on the Banyumas Regency Spatial Plan 2011 - 2031, the area of Banyumas Regency is approximately 138,915.52 ha, consisting of 37,971.21 ha of wetland agriculture, 45,155.01 ha of dryland agriculture, 17,020.78 ha of settlement, 28,513,31 ha of forests, and 10,255.21 ha of other allotments. According to the Ministry of Agriculture Regulation No. 5 of 2012, rice is one of the leading commodities that is the target of the national program in Banyumas Regency.

The altitude is 6 to 3,800 m above sea level, and the relief is flat to mountainous, consisting of alluvial, tectonic, and volcanic landforms. Soil formed belongs to the order inceptisols, andisols, alfisols, oxisols, and ultisols. Generally, soils formed on volcanic and alluvial landforms have a higher level of land productivity for agriculture (Maghfiroh dan Tafakresnanto, 2020). The temperature range from 27.78 °C to 27.90 °C, and the annual rainfall ranges from 2,789 mm to 4,253 mm.

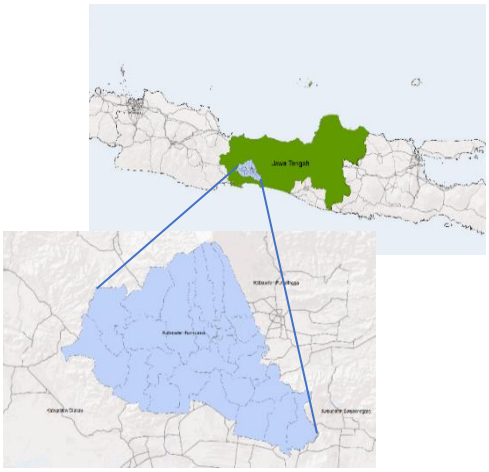

Figure 1. The study site, Banyumas Regency, Central Jawa, Indonesia.

Dataset use description

This research has used SPOT satellite imagery to map paddy fields, raw rice field maps, soil maps, and data on rice production, population, and rice demand. The dataset used is presented in Table 1. The research was conducted from August 2021 to July 2022. That comprised two activities, namely mapping multi-year paddy fields and calculating the potential loss of rice production due to conversion of paddy fields.

Table 1. Dataset used

Parameter	Material	Source	Revolution/Scale
Paddy field map 2007	SPOT2 2007	National Institute of Aeronautics and Space of Indonesia (LAPAN)	30 m
Paddy field map 2014	SPOT5 2014		20 m
Paddy field map 2019	SPOT7 2019		1.5 m
Paddy field 2019	Raw Paddy Field Map 2019	*Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN)*	1: 50,000
Rice production	Annual Report	*Banyumas District Agriculture and Food Security Service*	-
Number and population	Banyumas in Number	*Banyumas Regency Central Statistics Agency*	-
Rice needs	Basic Material Consumption	*Indonesian Central Statistics Agency*	-

Analysis of changes in the function of paddy fields

The analysis of rice field conversion was based on the results of the visual interpretation of SPOT images, namely SPOT2 (2007), SPOT5 (2014), and SPOT7 (2019) images obtained from the National Institute of Aeronautics and Space of Indonesia (LAPAN). The visual interpretation objects were classified into paddy fields and non-paddy fields.

The interpretation was carried out gradually, starting from the SPOT7 image using ArcGIS 10.8.2 software. It was done with the consideration that the accuracy of the interpretation results was based on the availability of the Basic Paddy Field Map from the Ministerial Decree of ATR/BPN No.686/SK-PG.03.03/XII/2019 regarding the Determination of National Basic Paddy Field Areas in 2019. Then, the interpretation of the SPOT5 image for paddy fields in 2014 was carried out regarding the

interpretation results of the SPOT7 and, subsequently, the SPOT2 with reference to the interpretation results of the SPOT5. This stage resulted in the distribution of paddy fields in Banyumas Regency in 2007, 2014 and 2019. The conversion of paddy fields was determined by overlaying the land distribution. The potential decline in rice production in a year is estimated by a simple mathematical formula, namely:

Potential decline in rice production = Conversion rate * Cropping index * Rice production ……. …[1]

RESULTS AND DISCUSSION

Paddy fields in Banyumas Regency

Paddy fields play a critical role in the food crop farming system, particularly in ensuring the availability of rice as the staple food for the majority of Indonesia's population. Considering their significance as a source of livelihood and employment for rural communities, the government has enacted protection policies through the Sustainable Agricultural Land Protection Act ("LP2B") and Government Regulation No. 1 of 2011, which regulates the designation and conversion of agricultural land. However, inconsistencies in data regarding the extent and location of paddy fields have often posed challenges for policy formulation, as differences in identification methods result in varying estimates of land area. To address this issue, the government undertook a nationwide mapping of paddy fields in 2019 to establish a single reference dataset for base paddy field areas. According to the Decree of the Minister of Agrarian Affairs and Spatial Planning/National Land Agency ("ATR/BPN") No. 686/SK–PG.03.03/XII/2019, the designated base paddy field area in Banyumas Regency covers 30,896.3 ha (Figure 2), distributed across elevations ranging from 6 to 700 meters above sea level, situated on volcanic, tectonic (structural), and alluvial (fluvial) landforms.

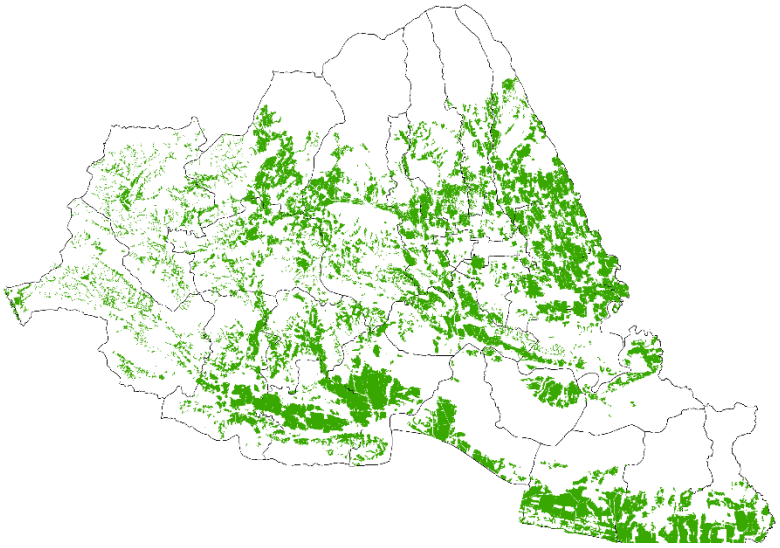

Figure 2. Distribution of base paddy fields area in Banyumas Regency

Referring to the Regulation of the Minister of Public Works and Public Housing ("PUPR") No. 14/PRT/M/2015 concerning the Criteria and Designation of Irrigation Areas, paddy fields in Banyumas Regency cover an area of 23,777.26 hectares (77%) classified as irrigated paddy fields, which are distributed across several irrigation areas. In addition, there are 7,119.05 hectares (23%) of non-irrigated paddy fields.

Based on production data compiled by the Department of Food Crops Agriculture of Banyumas Regency, there was a declining trend in both the cultivated area and the production volume of irrigated rice between 2018 and 2020. In 2018, the total cultivated area of paddy fields was recorded at 69,973.8 hectares, yielding a production volume of 406,071 tons. However, by 2020, the cultivated area had decreased to 62,781.0 hectares, with total production declining to 365,034 tons. During this period, the average cropping index (CI) was approximately 200% (CI200), with an average rice yield of around 5.8 tons per hectare. Detailed data on paddy production in Banyumas Regency are presented in Table 2.

According to data from the Indonesian Central Statistics Agency (Badan Pusat Statistik, 2021), the average rice consumption of the Indonesian population in 2019 was recorded at 103 kilograms per capita per year. The Banyumas in Numbers 2020 report states that the total population of Banyumas Regency in 2019 reached 1,840,152 people, with an average population density of 1,386 individuals per square kilometer. The annual population growth rate was recorded at an average of 0.9%. In terms of gender distribution, males constituted 50.44% of the population, while females accounted for 49.56%. The labor force represented 47.2% of the total population, comprising 61.37% males and 38.63% females. From a demographic perspective, the working-age population (15–65 years) dominated the population structure, accounting for 66.68%, followed by the age group 0–14 years at 24.50%, and the elderly population (>65 years) at 8.81%.

Table 2. Planted area and production of lowland rice in Banyumas Regency

No	Year	Harvest area (ha)	Production (t)	Productivity (t.ha^{-1})

1	**2022**	63,791	370,625	5.81
2	**2021**	63,747	372,909	5.85
3	**2020**	63,326	368,439	5.82
4	**2019**	63,973	364,949	5.70
5	**2018**	69,973	406,071	5.80
Rata-rata		64,962	376,599	5.80

Source: Department of Food Crops Agriculture, Banyumas Regency 2023.

Based on these figures, domestic rice production in Banyumas Regency remains in the surplus category. This calculation uses a conversion ratio from harvested dry paddy (GKP) to milled dry paddy (GKG) of 84%, and from GKG to rice of 64% (Badan Pusat Statistik, 2018). Consequently, the overall conversion rate from GKP to rice is approximately 54%. Population growth, accompanied by increased economic activity, drives greater demand for housing, economic infrastructure, food, and energy, ultimately exerting considerable pressure on land availability (Stavi and Lal 2015). In response to these demands, agricultural land often undergoes functional degradation and conversion, resulting in a quantitative reduction in productive land area. Without effective control over land-use conversion and improved food governance, maintaining the current surplus status will become increasingly difficult. Bondansari et al. (2024), stated that without controlling the rate of conversion of paddy fields and good food system management, based on a dynamic model, it is estimated that rice production in Banyumas Regency will start to experience a deficit in 2026, and rice self-sufficiency will only last until 2029.

The conversion of agricultural land is often regarded as a logical consequence of development processes and dynamic economic growth. However, this shift results in a reduction of rice production, which serves as the primary food source for the Indonesian population, thereby decreasing the contribution of domestic rice supply to national food reserves and increasing reliance on imported rice. The problem lies in the fact that maintaining rice self-sufficiency through imports becomes vulnerable when global rice supply chains are disrupted—such as through conflict and environmental stress linked to climate change (McKenzie & William, 2015). In addition to creating dependency on foreign rice sources, rice import policies can also negatively impact price stability at the farm level. The influx of imported rice into domestic markets tends to suppress the market price of locally produced rice, thereby harming farmers as the principal producers (Purbiyanti et al. 2017). For this reason, safeguarding and boosting national rice production is considered a strategic step toward reducing food dependency on other countries (Ruiz 2016; Clapp 2017). Nonetheless, such efforts face numerous complex challenges, ranging from production constraints and climate change impacts to issues related to land use policy and governance (Chaifetz and Jagger 2014)

Changes in The Function of Paddy fields in Banyumas Regency from 2007 to 2019

The results of the SPOT image interpretation showed that the paddy field area in Banyumas Regency from 2007 to 2019 continues to decrease (Figure 3). Based on the results of the SPOT image of visual interpretation above, it is known that the change in paddy fields in Banyumas Regency from 2007 to 2014 reached 473.9 hectares, from 2014 to 2019 is 756.8 hectares, and the overall average is 102.6 hectares per year. The damage to paddy fields in Banyumas Regency is concentrated around the urban distric (Purwokerto), the capital of Banyumas Regency (Figure 4).

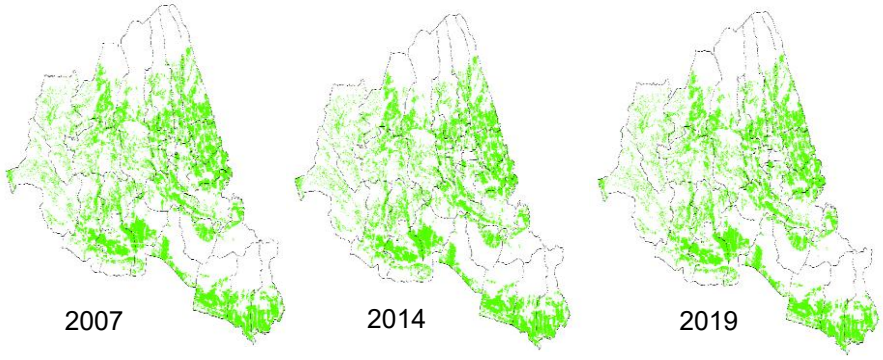

Figure 3. Distribution of paddy fields in Banyumas Regency in 2007, 2014 and 2019

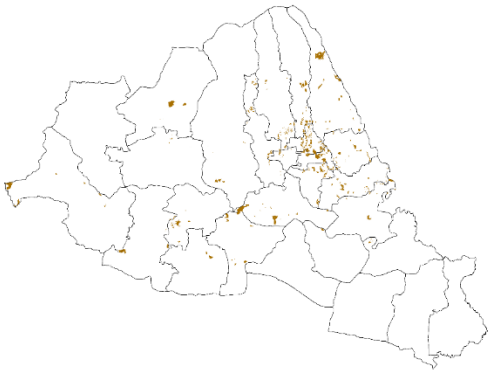

Figure 4. Distribution of converted paddy fields from 2007-2019

This fact can be understood as the development center of a region is a strong factor in attracting the conversion of agricultural land into residential areas and other supporting infrastructure. It is due to various conveniences and proximity to the center of various living needs, including economic activities, health, education, and access to transportation facilities (Kusumastuti et al. 2018; Farah et al. 2019; Siagian et al. 2019; Kaswanto et al. 2021). It provides an illustration that without government intervention, the conversion of agricultural land will follow economic principles, whereby land use activities tend to move towards those that generate a higher economic value of the land.

Several studies have indicated that paddy fields are more prone to land-use conversion compared to dryland areas (Murdaningsih et al. 2017; Nuraeni et al. 2017). This high vulnerability is influenced by various factors, including the typical proximity of paddy fields to residential or urban areas, better infrastructure availability, and relatively flat and accessible topography. Azadi et al. (2011) further emphasize that flat and fertile lands are more frequently targeted for conversion due to their higher accessibility and closeness to urban centers, which reduces infrastructure development costs and expedites implementation. In addition, strong driving factors for the conversion of paddy fields include the relatively lower land rent value of paddy fields compared to alternative land uses, and the weak governmental commitment to protecting agricultural land. The lower land value (land rent) of paddy fields compared to other uses means that the conversion of paddy fields is often difficult to control, and this condition is a serious threat to food security (Munibah et al. 2016; Barchia et al. 2021).

Land use change reflects human activities in utilizing and managing land resources. The change in land use from agricultural land to built-up land is a phenomenon that frequently occurs in several regions due to urban development (Wijaya and Susetyo 2017; Husin and Herwangi 2018; Allen 2019; Putri 2020). Agustamia et al. (2017)reported that between 1990 and 2000, Indonesia experienced a reduction of approximately 781,849 hectares of paddy fields, equivalent to an average annual loss of 78,184 hectares. Furthermore, Mulyani et al. (2016) estimated that the national rate of rice field conversion during the period 2000–2015 reached around 96,512 hectares per year. According to data from the Setyawan and Huda (2022), the total area of paddy fields in Indonesia in 2015 was 8,092,907 hectares, which declined by 628,956 hectares to 7,463,948 hectares in 2018. This corresponds to an average conversion rate of 157,240 hectares per year.

Changing paddy fields to other uses in various regions of Indonesia is not easy to prevent (Siagian et al. 2019). Conflicts of interest between individuals who want to use their land for higher economic purposes and the interest of the community and the nation to maintain the sustainability of existing paddy fields make preserving paddy fields difficult. Even more ironic if this phenomenon is interpreted as a logical consequence of population growth, economic development, and industrialization.

The results of several studies show that the factors driving the conversion of paddy fields into non-field land in a region are very diverse. Several factors driving it, both internal and external factors, include the socio-economic population (Alfiyah et al. 2017; Tejaningrum and Ardiansyah 2017; Yusuf et al. 2018; Farah et al. 2019), soil and land quality (Made et al. 2015; Padjung et al. 2021), accessibility (Siagian et al. 2019), infrastructure and policies (Kusumastuti et al. 2018)

With an annual rainfall between 2,789 mm to 4,532 mm, with a wet month (> 200 mm month^{-1}) and an average temperature of 25.78 ^{o}C to 27.90 ^{o}C, these paddy fields are potential for rice production (Ritung et al. 2011). Until now, the average cropping index is 200%, and the average productivity is 5,800 kg per ha, so with irrigation and cultivation technology engineering, rice production and productivity can still be improved. The results of a study on rice variety testing in several locations in Central Java showed varying productivity. In Jepara, the productivity of rice ranged from 7,700 to 9,500 kilograms per hectar (Suhendrata 2010), while in Sragen, it ranged from 6,230 to 7,250 kg per ha (Purwono and Hartono 2008).

The damage to the paddy field's function in this research area will affect rice production and lead to a further decline in domestic rice self-sufficiency. According to information from the Department of Agriculture and Food Security of Banyumas Regency, the average planting index in the Banyumas Regency area is twice a year, with an average rice productivity of 5,800 kilograms per year. The potential loss of rice production is 1,189,580 kilograms per year of harvested dry grain, equivalent to IDR 5,709,984,000.00. The average price of harvested dry grain in Central Java is IDR 4,800.00 (Badan Pusat Statistik Jawa Tengah 2020)

This phenomenon will threaten efforts to fulfill rice sufficiency and food sovereignty in the long term. Implementing new paddy field development programs is not easy due to various limitations. A more efficient action is protecting existing paddy fields from being easily converted to other uses. For this reason, it must be addressed with various efforts, including transformation in all aspects concerning policy and regulation, institution, biophysical, socio-economic aspects of the community, and technology. Efforts to control the rate of change in the use of paddy fields and ensure the supply of rice, namely the policy of making permanent paddy fields (Chofyan 2016), improving agricultural governance, increasing productivity, and improving the rice supply chain (Jamaludin et al. 2021).

Given the widespread conversion of paddy fields across various provinces, the government has taken strategic measures to safeguard food sovereignty, self-sufficiency, and national food security by enacting Law Number 41 of 2009 concerning the Protection of Sustainable Agricultural Land (UU LP2B). This regulation is intended to ensure the protection of agricultural land for food production at the national, provincial, and district/city levels. Its primary objective is to maintain the productivity of agricultural land and to promote its sustainable development in order to support the provision of staple food in a sovereign and self-reliant manner.

CONCLUSIONS AND SUGGESTIONS

From 2007 to 2019, a total of 1,230.7 hectares of paddy fields in the regency were converted to non-agricultural uses, with an average annual conversion rate of 102.6 hectares. This trend is expected to continue unless strict and consistent control measures are implemented. Such conditions would lead to a gradual decline in the domestic rice self-sufficiency level, with an estimated potential production loss of approximately 1,189,580 kilograms of harvested dry paddy (GKP) per year. The potential loss in paddy production in Banyumas Regency can be mitigated through the enforcement of regulations related to the protection of sustainable agricultural land (LP2B), the enhancement of the cropping index (CI) through improved irrigation management, and increased rice productivity by applying advanced cultivation technologies.

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