# Determinants of rice harvest allocation choices in several agroecosystems of Indonesia

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**Abstract.** The volume of grain supply from rice farming traded in the market determines rice price fluctuations. Information on farmers' behaviour in utilising rice harvests is strategic for knowing the volume of rice traded. This study analyses patterns and factors influencing farmers' behaviour using rice harvests. Primary data from the National Farmer Panel (PATANAS) were processed using quantitative methods with econometric models (multiple regression and double hurdle models). The results show that direct grain sales after harvest occur more often in irrigated and tidal rice agroecosystems. Meanwhile, indirect sales of harvested grain occur more frequently in lowland swamp agroecosystems and in rain-fed rice fields. The grain that is not sold immediately is allocated for household consumption and seed purposes and sold in stages. Factors that indirectly influence grain sales are the price of rice, the area cultivated, and the type of agroecosystem. When rice prices rise, farmers reduce the amount of grain they sell directly. The recommended policy recommendations are efforts to increase production in all agroecosystems and stabilise rice prices by strengthening government rice reserves, considering that not all harvested grain is traded.

## 1 Introduction

Food price stabilisation is a routine issue and one of the government's priorities. Rice is strategically positioned among food commodities because it is the staple food for 90% of Indonesia's population. Fluctuations in rice prices can significantly impact people's lives, especially those with low income. The stabilisation of rice prices indicates the balance between rice production, demand, and stock in the market. The analysis results of Widodo [1] show that the price of grain significantly influences the price of rice.

Rice is produced from farming, where the seasonal production pattern depends on water conditions. Differences in water conditions create differences in agroecosystems. In rice

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farming, there are four agroecosystems: irrigated, rain-fed, tidal, and swamp. The potential for planting rice in irrigated rice agroecosystems can reach three times in one agricultural calendar year: the rainy season, the first dry season, and the second dry season. However, in other agroecosystems, the potential for rice planting may only be one or two times a year. The level of rice production between agroecosystems also differs, and not all the grain produced by farmers can be circulated on the market.

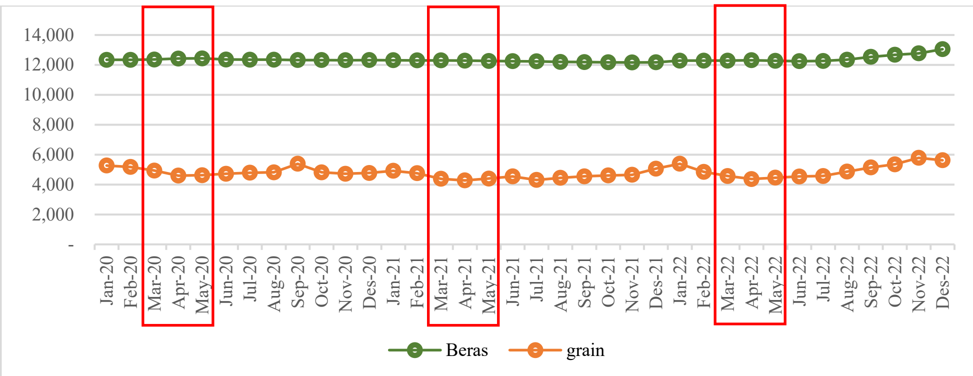


**Fig. 1**. Monthly development of grain and rice prices, 2020–2022 (IDR/kg).
Source: [2,3]

The use of rice produced, whether subsistence or commercial, is greatly influenced by the characteristics of the farmer's household and the type of rice farming business [4]. Farmers have different methods of selling grain, including direct, delayed, and staged sales. Farmers' decisions on how to use their harvest affect the amount of grain available on the market**.** If farmers hold on to their grains during periods of high demand, rice prices will increase. Figure 1 shows that the dynamics of grain prices greatly influence rice prices, even though there is a time lag of around 1–2 months. During the main harvest season (February-March), for example, there is a decline in the price of grain at the farmer level, but the price of rice at the retail level only falls about two months later (June or July).

The basic principle of the price stabilisation strategy is how to condition the rice supply in the market to be stable. The dimensions are not only the total volume but also the temporal distribution. Related to this, information regarding farmers' behaviour in utilising harvested rice is very important because farmers' decisions in selling their grain can significantly influence the availability of rice on the market. In this study, we examine the behaviour of farmers in using their rice harvests and identify the patterns and factors that influence it.

## 2 Methodology

The focus of this study is on how farmers allocate their harvest sales. It can be divided into two categories: (a) sold directly when harvested and (b) sold indirectly. In category (b), the harvested grain can be used for three purposes: saving for seeds, allocating for household consumption, and selling in stages. The proportion of each category varies between farmers. The factors influencing farmers' decisions in determining the proportions of each category include technical and socio-economic aspects.

### 2.1 Data types and sources

The data used in this study were survey data from the 2022 National Farmer Panel (PATANAS) from the Indonesian Center for Agricultural Socio-Economic and Policy

Studies, Ministry of Agriculture. The 2022 PATANAS survey was carried out in seven rice production centre villages, as seen in Table 1.

**Table 1**. Location and number of respondents of PATANAS, 2022.

| Agroecosystem | Province | District | Village | Number of respondents |
|---|---|---|---|---|
| Irrigated | Central Java | Cilacap | Padangsari | 40 |
| | East Java | Lamongan | Sungegeneng | 40 |
| Rainfed | Central Java | Grobogan | Jambon | 40 |
| | South Sulawesi | Bone | Tungke | 40 |
| Tidal | South Sumatra | Banyuasin | Telang Rejo | 40 |
| | | | Upang Karya | 40 |
| Swamp | South Kalimantan | Tanah Laut | Sumber Makmur | 40 |
| Total sample | | | | 280 |

## 2.2 Analysis method

The approach used in this research included (i) descriptive analysis to determine the allocation of rice harvest and (ii) econometric analysis to determine farmer behaviour in selling rice harvest. In context (ii), analyses were carried out regarding (a) factors that influence the proportion of harvest volume not sold directly and (b) factors that influence farmers' decisions to distribute their rice crops for sale at different stages. In analysis (ii. a), multiple regression was applied. Since the dependent variable is a proportion, the parameter estimates the generalised least squares (GLM) approach.

$$(Y)=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_5+\beta_4X_6+\beta_5X_7+\beta_6X_6+\beta_7D_1+\beta_8D_2++\beta_9D_3+\varepsilon_i \quad (1)$$

where:
g(Y) = identity link variable percentage of grain that is not sold directly
X1 = age of head of family
X2 = education of the head of the family
X3 = number of household members
X4 = rice field area
X5 = price of grain
X6 = price of rice
D1 = season dummy (0=rainy season, 1=dry season)
D2 = agroecosystems dummy
(1= irrigated; 2= swamp; 3= tidal; 4= rainfed)
D3 = dummy owned land (0= do not own, 1= own)

In analysis (ii. b), the decisions taken by farmers include two stages. The first is the decision to sell at different stages; second, if farmers decide to sell at different stages, how much will be sold. The double-hurdle model is appropriate for the possibility of using the same explanatory variables in both stages. The specific model is formulated as follows.

a. participation equation (farmers' opportunities to sell their crops):

$$d_i^*=a_0+a_1X_1+a_2X_2+a_3X_3+a_4X_4+a_5D_1+a_6D_2+U_i \quad (2)$$

b. the equation for the percentage of harvest sold in stages:

$$y_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_5 + \beta_4 X_6 + \beta_5 X_7 + \beta_6 D_1 + V_i \quad (3)$$

$$y_i = \begin{cases} x_i\beta + \varepsilon_i & \text{if min } (x_i + \varepsilon_i \text{ , } z_i\gamma + u_i) > 0 \\ 0 & \text{other} \end{cases} \quad (4)$$

where:
di = opportunity for farmers to sell their crops (0=not sold in stages, 1=sold in stages)
yi = the percentage of harvest that is sold in stages
αi, i:0, …,6 = parameter estimation of farmer participation variables
βi, i:0, …,6 = estimation of grain intensity variable parameters sold in stages
X1 = education of the head of the family
X2 = working household members
X3 = percentage of household members working in agriculture
X4 = area of cultivated rice fields
X5 = age of head of family
X6 = number of household members
X7 = price of rice
D1 = season dummy (0=rainy season, 1=dry season)
D2 = rice field dummy (0=technical irrigation, 1=non-technical irrigation).

# 3 Results and discussion

## 3.1 General description

Generally, milled dry grain production in 2022 will be 55.67 million tons, or an increase of 2.3% compared to 2011, which was 54.42 million tons. With the conversion of milled dry unhusked grain to rice of 64.02% [2], national rice production in 2022 will be 35.64 million tons. On the other hand, the prognosis for rice demand is estimated at 30.86 million tons [5]. This means that, in aggregate, there is still a surplus of 4.78 million tons.

Even though there is an aggregate surplus, the dynamics of the monthly rice balance still experience a deficit in certain months because production levels are seasonal, whereas the need for rice per month is relatively fixed. Generally, the harvest season is divided into two in Indonesia, namely the rainy season harvest in the range of February, March, and April, and the dry season harvest in the range of August, September, and October. Figure 2 shows that the 2021 and 2022 harvests occurred in the rainy season (March-April), while during the dry season, grain production remained relatively constant and even decreased in November, December, and January. If, during the dry season harvest, farmers do not immediately sell their grain, then less grain will enter the market, potentially pushing up rice prices.

Rice fields in Indonesia consist of irrigated, rain-fed, tidal, and swamp, with a total area of 8.1 million ha [6]. Differences in the types of rice fields managed by farmers influence the intensity of rice planting, as shown in Figure 3. The intensity of rice planting in rice fields with smooth irrigation and water drainage systems will be greater than that in rice fields with less smooth irrigation and water disposal systems.

Irrigated rice agroecosystems have the highest planting intensity of the four types of agroecosystems. In Indonesia, 67.5% of rice fields are irrigated, and in 2020, 74% of fresh water was used for irrigation [4]. Farmers in irrigated rice fields can generally plant rice two to three times a year with sufficient water availability. In swamp rice agroecosystems, most farmers plant rice twice a year. Concerns about the Musi River overflow are dominant among farmers, who only plant rice twice a year. In rain-fed rice agroecosystems, farmers generally only plant rice once a year, but also plant other commodities. The cropping patterns most commonly found in rainfed rice fields are rice-maize-maize (31.17%), rice-vegetables-corn (16.21%), and rice-maize-soybeans (13.71%). The tidal rice agroecosystem is a rice field that is flooded almost all year round. Around 80% of farmers in this ecosystem can only plant rice once a year with local rice varieties such as *Siam Arjuna*, *Siam Pandak*, and *Siam Rantau*, which are resistant to waterlogging. The lifespan of local rice from planting to harvest can reach 7–8 months [6].

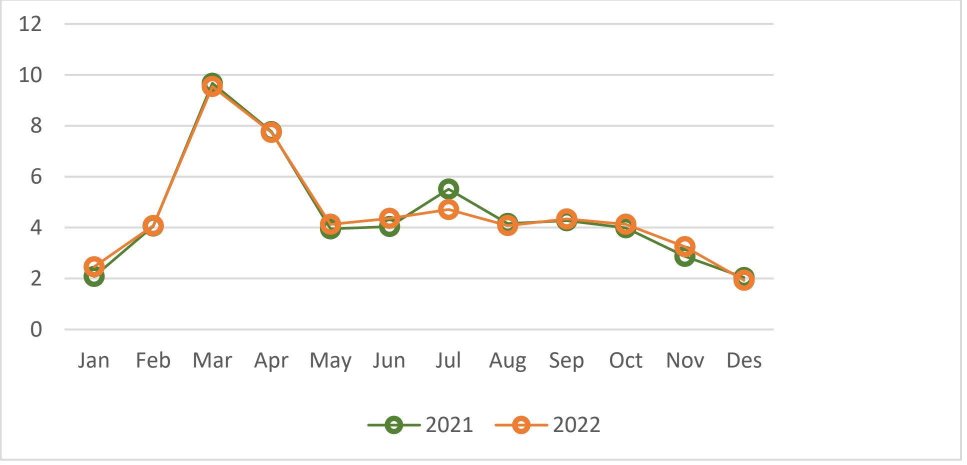


**Fig. 2**. Development of monthly grain production, 2021–2022 (million tons).
Source: [3]

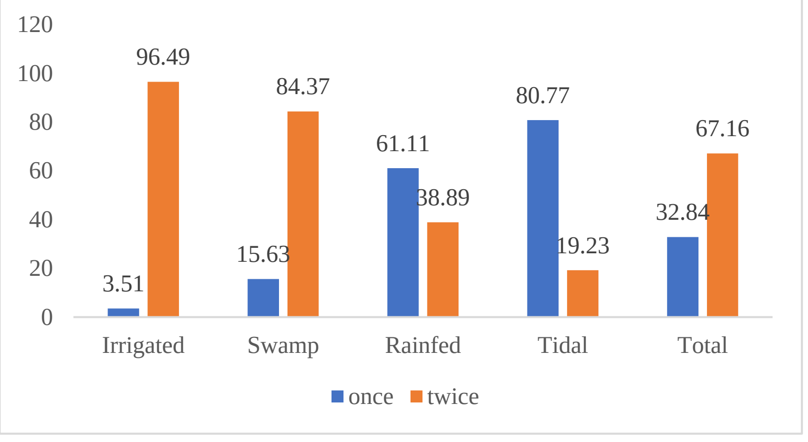


**Fig. 3.** Rice planting intensity at the PATANAS location, 2022.

Apart from planting intensity, productivity is the key to increasing production. Rice productivity in irrigated agroecosystems was the highest compared to other rice fields (Table 2). Appropriate allocation of quantity and quality production factors will affect productivity [7–9].

In general, irrigated rice agroecosystems have the highest level of productivity compared to other agroecosystems. In irrigated rice fields, rice productivity in the rainy season is slightly lower than that in the dry season due to flooding at several study locations. There will be more rainy days in 2021–2022 compared to previous years. In rainfed rice agroecosystems, rice productivity in the rainy season is higher than that in the dry season because water needs are sufficient in the rainy season. According to Sumaryanto et al. [10], the results of the first and second planting seasons were relatively high, provided that the allocation of production factors was optimal. In tidal rice agroecosystems, the level of productivity is the lowest compared to other agroecosystems because environmental stress is higher [1,11]. The rice productivity level of 2.28 tons per ha is relatively moderate. However, it can still be increased, considering that the level of rice productivity in tidal rice agroecosystems can reach 4–5 tons per ha [12]. A significant decrease in rice productivity occurs in swamp rice fields between the rainy and dry seasons. River water overflow was greater in the rainy season. Most farmers failed to harvest due to flooding, resulting in crop yields that were much lower than normal. Rice farming in tidal and swamps requires the application of very varied technologies, such as managing water, soil, and nutrients and using varieties that are tolerant of land conditions [13,14].

**Table 2.** Rice productivity by the type of rice field (kg/ha).

| Type of rice field | Rainy season | Dry season | Average |
|---|---|---|---|
| Irrigated | 5.826 | 5.910 | 5.868 |
| Rainfed | 3.930 | 3.189 | 3.811 |
| Tidal | 2.273 | 2.547 | 2.284 |
| Swamp | 4.783 | 1.894 | 3.474 |
| Total | 4.581 | 3.894 | 4.314 |

### 3.2 Farmer's behaviour in allocating rice harvest

Factors influencing economic behaviour are risk, uncertainty, and profit factors [15]. Household economic well-being and social relationships between farmers and rice traders are the main factors that affect rice harvest allocation. Rice is a subsistence commodity [16]. In this case, farmers act as producers and can also act as consumers. Direct sales are driven by getting money as quickly as possible, which can be used for various purposes, such as paying debts, farming costs, and meeting household needs.

Farmers who carry out direct sales generally rely on rice farming as their primary source of income, control relatively small amounts of land, and belong to the lower economic strata. The pressure to fulfil the family's financial needs is one of the causes of the low bargaining power of rice farmers in an oligopsony grain market structure [17].

Indirect grain sales can be considered as grain reserves stored in farming households. The amount of grain reserves at the farming household level is the difference between the volume of harvested grain and that sold directly. Farmers can use these grain reserves to stock seeds for the next planting, grind them into rice for household consumption, or sell them in stages.

#### *3.2.1 Direct grain sales*

The proportion of grain sold directly at harvest according to agroecosystem type and planting season is shown in Table 3. The number of farmers who sell grain directly during the dry season is lower than that during the rainy season, except for farmers in irrigated rice-field agroecosystems. Considering that the risk of storing grain is relatively high, research results in Bangladesh showed that the yield loss of stored grain was around 10% [18].

The proportion of farmers who sold and the proportion of grain sold differed between agroecosystems, but there were three patterns. First, the proportion of farmers who sell grain directly does not change much between the seasons. This condition occurs in irrigated rice agroecosystems. Rice harvesting using the slash system can be interpreted as direct sales. This condition is often found in research locations. With direct sales, it is estimated that around 60% of the harvested grain is directly absorbed in the market. Second, the proportion of farmers who sell their crops directly in the dry season is less than that in the rainy season, but the proportion of rice they sell is higher. This condition occurs in the agroecosystems of tidal and rainfed rice fields. Third, the proportion of farmers who sell and the proportion of grain sold directly are very high, and in the rainy season, the proportion is higher than that in the dry season. This condition occurs in the swamp rice agroecosystem; a large portion of grain is directly sold because all farmers use combine harvesters at harvest. The owners of these combine harvesters usually double as traders collect grain. More people sell directly during the rainy season because farmers do not have drying facilities.

Generally, the grains circulating in the market are mostly from irrigated rice fields and swamp agroecosystems. In both agroecosystems, rice was the main commodity cultivated for commercial purposes. Meanwhile, more grain produced in tidal and rainfed agroecosystems will be stored because both agroecosystems are subsistence farmers, and rice is not the main commodity. If we look at the season, much grain will be circulating in the market during the rainy season because, apart from abundant production, farmers' limitations in drying and storage are the main factors causing farmers to sell grain directly. In this way, the government can carry out planning regarding food reserves. During the rainy season, in irrigated rice fields and swamp areas, the government can absorb grain so that prices do not drop and store it as food reserves. Food reserves can be used to withstand price spikes during the dry season when production falls, and more farmers hold back their grain to store as family food reserves.

**Table 3.** Proportion of farmers who sell dry grain directly after harvest.

| Type of rice field | Rainy season | | Dry season | |
|---|---|---|---|---|
| | Farmer (%) | Sale (%) | Farmer (%) | Sale (%) |
| Irrigated | 75.44 | 60.36 | 78.95 | 60.24 |
| Tidal | 15.38 | 7.39 | 11.54 | 60.00 |
| Swamp | 98.44 | 82.37 | 78.13 | 69.56 |
| Rainfed | 61.11 | 37.46 | 31.48 | 53.88 |
| Total | 71.14 | 54.36 | 57.21 | 62.79 |

### *3.2.2 Factors affecting the proportion of indirect grain sale*

The estimation results show that the factors that have a significant indirect influence on the proportion of grain sold are cultivated area (negative), rice price (positive), and the rice field type dummy (Table 4).

Based on the analysis results, the variables with real influence can be explained as follows. The cultivated land area, which is the proportion of grain sold indirectly, will be smaller if the cultivated land area is larger. The wider the cultivated area, the greater the grain production. The problem is that the grain storage space is inadequate; therefore, it would be more efficient if the grains were sold directly. Apart from that, farmers with large land areas generally have high household incomes, so they do not need to store too much grain for consumption. The price variable that has a real influence on farmers' decisions to determine the proportion of grain that is not sold directly is the price of rice rather than the price of grain. This result indicates that farmers' decision not to sell grain directly anticipated a possible increase in rice prices. The proportion of grains sold indirectly by farmers in tidal and rainfed rice fields was higher than that of farmers in technically irrigated rice fields. Field observations have shown that rice farming in these two agroecosystems is more subsistence-oriented than commercial farming [19].

**Table 4.** Factors influencing the proportion of harvested produce that is not sold directly.

| Variable | Coefficient | Std. Err. | P>\|z\| |
|---|---|---|---|
| Age of head of family | -0.034 | 0.169 | 0.839 |
| Education of the head of the family | -0.836 | 0.565 | 0.140 |
| Number of household members | 0.862 | 1.023 | 0.400 |
| **rice field area** | **-4.022** | **1.147** | **0.001** |
| Price of grain | 0.005 | 0.003 | 0.110 |
| **Price of rice** | **0.005** | **0.002** | **0.012** |
| season dummy (0=rainy season, 1=dry season) | -5.055 | 3.317 | 0.129 |
| agroecosystem dummy (control=irrigated rice fields) | | | |
| **Tidal** | **44.220** | **6.402** | **0.000** |
| Swamp | -12.155 | 6.139 | 0.049 |
| **Rainfed** | **18.507** | **5.018** | **0.000** |
| owned land dummy (0=do not own, 1=own) | -1.754 | 4.477 | 0.695 |
| _cons | -13.361 | 27.552 | 0.628 |

### *3.2.3. Factors affecting farmers' opportunities in selling rice in stages*

Gradual grain sales are a part of grain that is not sold directly by farmers. The estimation results show that the factors that influence farmers' opportunities to sell their harvests in stages are the education of the family head (positive), percentage of household members working in agriculture (positive), and area of rice fields cultivated (negative) (Table 5).

Based on the analysis results, the variables with significant effects can be explained as follows. Education of the head of the family: heads of families with a higher level of education will think speculatively in responding to grain prices. If the price of grain is low, the opportunity for farmers to delay selling their grain increases. This is in line with previous research results [20]. The percentage of household members who work in agriculture and the number of household members who work in agriculture means that decisions in allocating harvested grain are not centred on the head of the household alone. It takes time to make decisions together, so harvested grain is usually brought home and not immediately sold. The area of rice fields cultivated is a factor that influences direct sales. The opportunity for gradual sales by farmers with large cultivated areas was relatively small. Farmers with large areas of land have difficulty storing their grain and cultivating their land with a commercial orientation.

For farmers who decide to sell their grain in stages, the factor that influences the proportion of grain sold in stages is the age of the family head (positive). It means that the higher the age of the head of the family, the proportion of grain sold gradually increases. Older farmers have a high level of concern about their household consumption. Grain sold in stages can become a reserve for household consumption if there is a shortage. This motive becomes stronger because the influence of rice prices on sales gradually becomes positive (if the significance level is increased by 6%). This condition further emphasises that rice farmers are net consumers, so increasing rice prices does not directly encourage grain sales but encourages farmers to sell in stages.

**Table 5.** Factors influencing grain sales in stages.

| Variable | Participation | | Intensity | |
|---|---|---|---|---|
| | Coeff | P>\|z\| | Coeff | P>\|z\| |
| Education of the head of the family | **0.0586** | **0.042** | 1.3620 | 0.206 |
| Working household members | -0.1179 | 0.307 | -7.7203 | 0.136 |
| % of household members working in agriculture | **0.0069** | **0.037** | | |
| Rice field areas | **-0.2975** | **0.004** | | |
| Age of head of family | | | **0.7533** | **0.019** |
| Number of household members | | | -0.1704 | 0.947 |
| Price of rice | | | 0.0082 | 0.059 |
| Season dummy (0=rainy season, 1=dry season) | -0.3439 | 0.082 | -5.8703 | 0.495 |
| Rice field dummy (0=technical irrigation, 1=non-technical irrigation). | 0.2068 | 0.323 | | |
| _cons | -1.1559 | 0.009 | -76.6611 | 0.061 |
| /sigma | 22.4833 | | | |
| /covariance | 9.6496 | 0.401 | | |

# 4 Conclusions and policy recommendations

Rice farming has varying levels of planting intensity and productivity across agroecosystems. The highest planting intensity and productivity were found in irrigated rice agroecosystems, which have a better water management system than other agroecosystems.

The proportion of indirect sales of harvested produce (postponed sales) is influenced by the cultivated area (negative), the price of rice (positive), and the dummy of rice field type (the proportion of grain sold indirectly by farmers in the swamp and rain-fed swamp agroecosystems is higher than that of farmers in irrigated rice agroecosystems). Factors that influence farmers' opportunities to sell their crops in stages are the education of the family head (positive), the percentage of household members who work in agriculture (positive), and the area of rice fields cultivated (negative). For farmers who decide to sell their grain in stages, the factors that influence the proportion of grain sold in stages are the age of the family head (positive) and the price of rice (positive). Based on the test results, it can be concluded that not all harvested grains are sold directly or indirectly. With various influencing factors, farmers decide to sell or store harvested grain. The behaviour of farmers in utilising their harvest can be used as a reference by the government to determine when to hold food reserves and when to spend food reserves to maintain rice price stability.

Based on the above conclusions, the following policy recommendations can be suggested. To increase rice production in all agroecosystems, it is necessary to increase the planting intensity and productivity. The development of superior rice varieties in tidal agroecosystems needs to be improved because they still have the potential to increase planting intensity and productivity, including through irrigation management. Improvements to the water system in irrigated and swamp rice agroecosystems also need to be made to increase the planting intensity and productivity.

The government can absorb the maximum amount of grain during the rainy season harvest and store it as food reserves. Food reserves can be released during the dry season when production falls, and less grain circulates in the market to withstand price increases.

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