Climate-smart adaptation strategies of inpari nutri zinc rice farmers in Bantul, Indonesia

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Abstract. Climate change increases rainfall uncertainty and lengthens dry spells in Bantul, raising production risks for Inpari Nutri Zinc rice farmers. This study analyses climate-smart adaptation strategies and their determinants in three villages of Imogiri Subdistrict, Bantul, Indonesia. We carried out a census of 125 Inpari Nutri Zinc farmers in Kebonagung, Wukirsari, and Selopamioro and collected data through face-to-face structured interviews. We used descriptive statistics, an adaptation index, and binary logistic regression to measure farmers' adaptation levels and identify factors that influence each strategy. Farmers apply several climate-smart practices: advancing or delaying planting dates, using the pranata mangsa seasonal calendar, operating pumps during dry spells, strengthening crop-management practices, and diversifying into non-rice crops. Wukirsari and Selopamioro farmers show higher adaptation scores than Kebonagung farmers. Levels of education, size of farmland, income, years of farming, gender, land ownership status, involvement in farmer groups, and access to weather information all play a significant role in whether farmers adopt at least one adaptation strategy, while household size has no meaningful influence. The findings show that stronger climate information services, more effective farmer groups, and better access to climate-resilient technologies are needed to support climate-smart readiness and sustain Inpari Nutri Zinc cultivation in this stunting-prone area

1 Introduction

Rice is a primary agricultural commodity and the main staple food for most of the Indonesian population. Inpari Nutri Zinc is a breakthrough rice variety promoted by the government as a high-zinc rice to help reduce micronutrient deficiencies and stunting among children [1,2]. Bantul Regency in the Special Region of Yogyakarta has been designated as one of the development areas for Inpari Nutri Zinc rice because it contains several stunting hotspots [3,4]. The successful adoption and sustained cultivation of this biofortified variety therefore depend on how farmers respond and adapt to changing climatic conditions.

Climate change is a long-term phenomenon that statistically changes weather patterns over a period of decades to millions of years. One of the impacts is an increase in air temperature, where temperatures in Indonesia have increased by around 0.1 degrees Celsius

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in the last 30 years. This warming also has an impact on the increasingly dry season, with a decrease in rainfall of up to 20%. Therefore, farmers need to be equipped with knowledge that allows them to understand and utilize information related to climate and weather predictions [5], with this understanding, they can adjust planting times, cultivation patterns, and types of crops planted to still obtain optimal harvest results even when facing uncertain weather conditions [6]. Through this adaptation strategy, farmers can also determine more appropriate planting and harvest times to reduce the risk of extreme weather

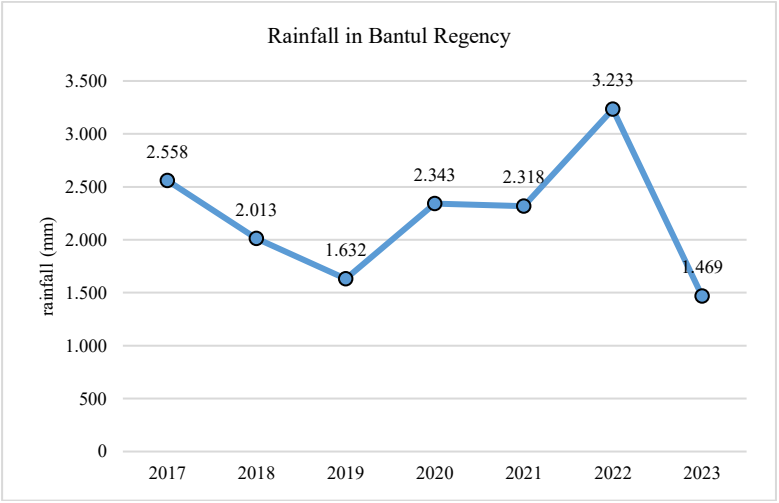

Fig 1. Rainfall in Bantul Regency (mm)

In 2023, there was a decrease in rainfall, amounting to 1,469 mm per year, as shown in Figure 1. It is noted that this period corresponds to the planting season for Inpari Nutri Zinc rice farmers. Changes in rainfall patterns due to climate change have become a significant barrier to agricultural activities. The low rainfall increases the risk of crop failure. Additionally, it makes it difficult for farmers to manage their land effectively. Climate change refers to natural alterations, but it is also influenced by human activities that can modify temperature and weather patterns over extended periods Farmers in Bantul Regency experience a variety of climate-related hazards, including crop pests, animal diseases, insect attacks and extreme temperature events. Farmers are particularly vulnerable to climate change-related hazards due to a lack of adequate infrastructure, high levels of poverty, and limited water supplies. Farmers in the study area say that the main negative impacts of climate-related risks are water scarcity, changes in the planting calendar, and uncertainty or reduction in crop yields. Bantul Regency has a tropical monsoon climate, with the rainy season lasting from October to March and the dry season lasting from April to September. The lack of rain from October to November causes drought conditions on farmland. Because of this, farmers, especially in Imogiri, must wait to plant their rice. As a result, there is a decline in productivity, as indicated by the productivity data of Inpari Nutri Zinc rice farmers in Bantul Regency in 2023. These conditions raise the likelihood of crop failure and make farmers struggle to decide the timing and management of Inpari Nutri Zinc rice planting. Inpari Nutri Zinc farmers in Bantul Regency show the impact of these climatic pressures in their productivity levels [4,7]

Table 1 presents the planted area, harvested area, and yield for each planting stage, and captures how these farmers responded to the changing weather during the year. The land area under Inpari Nutri Zinc was initially larger in the first planting stage but declined in later stages, and average yields also varied between locations. Some villages did not always

receive seed assistance at the same time, so only part of the irrigated and rainfed land could be planted with Inpari Nutri Zinc in each stage [6].

Table 1 Productivity of Inpari Nutri Zinc rice in Bantul Regency

No.	Subdistrict	Land Area (Ha)		Productivity (Tons/Ha)	
		Stage 1	Stage 2	Stage 1	Stage 2
1	Imogiri	122	107	7.76	7.77
2	Bantul	234	-	8.18	-
3	Sewon	17	-	7.36	-
4	Srandakan	3	-	5.6	-
5	Sedayu	11	-	9.6	-
6	Banguntapan	50		8.54	

Inpari Nutri Zinc farmers in Bantul face decisions about which combination of these strategies is feasible given their resources, knowledge, and access to information. Previous studies show that several socio-economic and farm characteristics influence farmers' adaptation decisions[8,9]. Age, gender, education, and farming experience shape farmers' perceptions of climate risk and their willingness to change established practices [9,10]. Larger landholdings and secure land ownership can increase the capacity to invest in new technologies or switch varieties. The same time, distance to markets, farm income, and access to climate and weather information affect how quickly and accurately farmers respond to changing conditions [11,12]. However, most of this evidence comes from conventional rice systems or mixed cropping systems and does not focus on biofortified varieties. a growing body of research has examined farmers' adaptation responses to climate variability in rice-based systems, empirical evidence remains limited for biofortified rice varieties that are explicitly promoted to address malnutrition [1–4]. Existing studies generally focus on conventional paddy farmers, broad climate percepti ons, or single composite indices of adaptation, and rarely consider how farmers adjust their practices when cultivating Inpari Nutri Zinc in stunting-prone areas. The interaction between climate stressors, site-specific agro-ecological conditions, and nutrition-sensitive varietal adoption is therefore not yet well understood. Many earlier studies also treated adaptation as a single, uniform decision. They did not distinguish between specific strategies, such as advancing or delaying planting, using traditional seasonal calendars, investing in water management technologies, improving crop management, or diversifying crops [8,12]. This study addresses these gaps by focusing on Inpari Nutri Zinc farmers in a hotspot of child stunting and by examining multiple adaptation strategies that are directly linked to changing rainfall patterns and increasing climate risks.

Accordingly, this study pursues two objectives. First, it identifies the adaptation strategies that Inpari Nutri Zinc rice farmers use in response to climate change. Second, it examines how socio-economic, institutional, and farm-level factors shape the probability that farmers adopt each of these strategies by disaggregating adaptation into distinct, observable actions, the analysis provides a more nuanced picture of how farmers respond to climatic stress in a nutrition-sensitive rice system [13]. This study extends current scholarship by directly linking farmers' climate adaptation practices with the promotion of a biofortified rice variety in a stunting-prone setting, thereby advancing the discourse on climate-smart and nutrition-sensitive agriculture. The results can guide policymakers and development practitioners in designing extension services, climate information systems, and support programs that build

farmers' resilience, maintain the use of Inpari Nutri Zinc, and improve local food and nutrition security.

2 Material and Methods

2.1 Study Area

The study was conducted in Imogiri Subdistrict, Bantul Regency, Yogyakarta, Indonesia, focusing on Kebonagung, Wukirsari and Selopamioro villages. These sites were purposively selected because farmers in these villages received Inpari Nutri Zinc seed support and have been exposed to declining rainfall intensity and more frequent dry spells in recent years [4]

2.2 Sampling and data collection

The target population consisted of all Inpari Nutri Zinc rice farmers in the three selected villages. The study used a census approach, so every farmer cultivating Inpari Nutri Zinc in Kebonagung, Wukirsari and Selopamioro was included in the sample. In total, 125 farmers were interviewed. Primary data were collected through face-to-face structured interviews using a pre-tested questionnaire. The questionnaire captured farmers' socio-economic characteristics, farm characteristics and adaptation practices related to climate change. Secondary data, including rainfall records and supporting statistics, were obtained from relevant local government agencies

2.3 Measurement of adaptation strategies and explanatory variables

The study examined six climate-smart adaptation strategies implemented by Inpari Nutri Zinc rice farmers: (i) advance planting time, (ii) delayed planting time, (iii) use of the *pranata mangsa* (traditional Javanese seasonal calendar), (iv) use of water pumps for irrigation, (v) crop-management practices and (vi) crop diversification. For each strategy, farmers were asked whether they practiced it during the 2023 season. Each adaptation strategy was coded as a binary dependent variable, where a value of 1 indicates that the farmer adopted the strategy and 0 indicates otherwise

To capture overall adaptation level, the questionnaire also recorded the intensity of several adaptation indicators, including crop diversification, crop management, use of pumps, reliance on the pranata mangsa calendar, delayed planting time and advanced planting time. These indicators were measured using a Likert-type scale and then aggregated into an adaptation score for each farmer. The total scores were grouped into four categories: not adaptive, less adaptive, quite adaptive and adaptive (Table 3). Higher scores indicate a more active and consistent adaptation behaviour.

Table 2. Adaptation of Inpari Nutri Zinc rice farmers

No	Category	Adaptation
1	Not Adaptive	6.00 – 10.50
2	Less Adaptive	10.51 – 15.00
3	Quite Adaptif	15.01 – 19.50
4	Adaptive	19.51 – 24.00
	Maximum Score	24.00
	Minimum Score	6.00

Explanatory variables include both socio-economic and farm-level characteristics. Continuous and discrete variables comprise age (years), land size (m²), farming experience (years), number of family members and annual household income (IDR/year). Ordinal education level distinguishes farmers with no formal schooling, primary, junior secondary, senior secondary and higher education. Dummy variables capture gender (male/female), active search for weather or climate information (yes/no), land ownership status (owned/rented or profit-sharing) and participation in farmer groups (active/inactive).

2.4 Econometric Model

Binary logistic regression was used to analyse the factors that influence the probability that a farmer adopts each adaptation strategy. For a given strategy, the model can be written as:

$$ln\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X + \beta_6 X_6 + D_1 + D_2 + D_3 + D_4$$

where P is the probability that a farmer adopts the adaptation strategy (Y = 1), β_0 is the intercept and $\beta_1, \ldots, \beta_k$ are parameters associated with the explanatory variables $X_1, \ldots, X_k$.In this study, $X_1$to X_6represent age, education, land size, farming experience, number of family members and income, respectively. Additional dummy variables capture gender, search for climate information, land ownership status and farmer-group participation. For each strategy, the dependent variable takes the value 1 if the farmer implements the strategy (e.g. advances planting time, delays planting time, uses the *pranata mangsa*, operates pumps, applies crop-management practices or diversifies crops) and 0 otherwise. Logistic regression coefficients and odds ratios are estimated separately for each of the six strategies. The goodness of fit of each model is assessed using the Hosmer–Lemeshow test, together with the –2 log-likelihood and Nagelkerke R-square statistics, to ensure that the specified models adequately describe the observed data

3 Results and Discussion

3.1 Socio-economic characteristics of Inpari Nutri Zinc farmers and their adaptive capacity

At village level, the socio-economic profile of Inpari Nutri Zinc farmers shows clear contrasts that help explain the differences in adaptation reported in the abstract. Selopamioro is characterised by older farmers, very small plots, and low education, combined with relatively secure land ownership. Wukirsari has the largest number of farmers, with low education, long farming experience, small landholdings, and the highest share of households in the lowest income class. Kebonagung farmers tend to have higher education, larger plots, and slightly better income, but are more specialised in irrigated rice. These village-specific conditions shape farmers' exposure, resource base, and decision space for climate-smart adaptation. A summary of key characteristics by village is presented in Table 3.

This pattern reflects the dominant role of men in decision-making for paddy cultivation, although women often participate in post-harvest and household-level food management. The age distribution shows that most farmers belong to older age groups. In Selopamioro and Kebonagung, many respondents are between 60–68 years, and Selopamioro has a sizeable group of farmers aged 69–77 years. This age structure indicates that Inpari Nutri Zinc cultivation is dominated by senior farmers who possess substantial experiential knowledge but may face physical constraints in implementing labour-intensive adaptation practices.

Table 3. Socio-economic characteristics of Inpari Nutri Zinc rice farmers

Variable	Measure	Selopamioro	Wukirsari	Kebonagung
Number of farmers	n	32	71	22
Gender	Male farmers (%)	93.8	90.1	90.9
Age	Dominant age group (years)	69–77	60–68	60–68
Education	Primary education or less (%)	59.4	64.8	31.8
Farming experience	Farmers with ≥ 29 years' experience (%)	71.9	71.8	59.1
Landholding	Farmers with < 2,000 m² (%)	87.5	63.4	36.4
Land ownership	Own land (%)	81.2	52.1	68.2
Monthly income	Lowest income class* (%)	50	57.7	31.8
Weather information	Actively seeking weather info (%)	28.1	29.6	31.8
Farmer group participation	Active members of farmer groups (%)	93.8	94.4	90.9

*Lowest income class = IDR 700,000–2,560,000 per month.

Formal education is generally low. Across the three villages, more than half of the farmers have only primary schooling or no formal education. Kebonagung has a somewhat higher share of farmers with junior and senior high school education, whereas Selopamioro and Wukirsari are dominated by primary school graduates. Limited formal education can reduce farmers' ability to access and interpret technical climate information, yet long-term experience may partially compensate for this constraint. The coexistence of low education and long farming experience suggests that many farmers rely on experiential learning and local indicators rather than formal climate advisories [12]

Farming experience is long in all villages. Many farmers have cultivated rice for more than 29 years, and in Kebonagung some report over 40 years of experience. Most farmers operate small plots. In Selopamioro and Wukirsari, the largest group farms 100–2,000 m², while Kebonagung has more farmers with land areas above 3,000 m². Land is predominantly owned rather than rented or sharecropped, especially in Selopamioro and Kebonagung. These conditions imply that farmers have strong attachments to their land and long-term responsibility for managing climate risk, but the small scale of operations can limit their financial capacity to invest in costly adaptation technologies such as pumps or on-farm water storage

Household sizes are modest. Most households consist of 1–4 members, and only a small fraction has more than six members. Farm and non-farm income remain low; over half of farmers in each village fall into the lowest income class, and only a few reports higher income levels. Limited income may constrain the adoption of adaptation measures that require upfront investment, even when farmers are aware of the benefits. At the same time, low income and small landholdings increase farmers' vulnerability to crop failure, highlighting the importance of low-cost and knowledge-based adaptation options. Awareness and use of climate information are limited. In all three villages, most farmers do not actively seek weather forecasts from formal sources. In contrast, participation in farmer groups is very high. More than 90% of farmers report being active members of a farmer organization. This configuration suggests that farmer groups could serve as an important channel for

disseminating adaptation-related information, even though they have not yet been fully leveraged for that purpose. Strengthening the role of farmer groups in climate information sharing and joint decision-making may therefore be a promising entry point for future interventions.

3.2 Adaptation strategies and adaptation index across villages

Farmers implement several strategies to cope with increasing climate variability. These include advancing planting time, delaying planting, using the pranata mangsa (traditional Javanese seasonal calendar), using pumps for irrigation, strengthening crop management (especially pest and disease control), and diversifying crops. The six indicators are combined into an adaptation index that classifies farmers as not adaptive, less adaptive, quite adaptive, or adaptive. This index captures the intensity and consistency of farmers' responses rather than focusing on a single measure. Overall, Inpari Nutri Zinc farmers in Selopamioro and Wukirsari fall into the "quite adaptive" category (Figure 2).

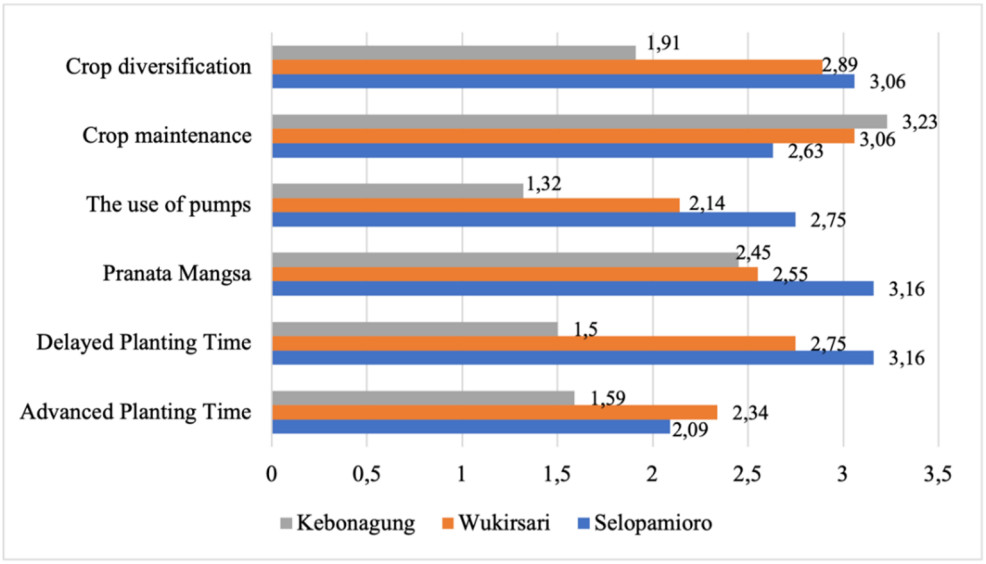

Fig 2. Adaptation levels of Inpari Nutri Zinc rice farmers to climate change in Selopamioro, Wukirsari, and Kebonagung

Figure 2 summarises the distribution of adaptation categories across the three study villages. Farmers in Wukirsari and Selopamioro are predominantly classified as quite adaptive or adaptive, while a larger share of farmers in Kebonagung remain in the less adaptive category. These differences suggest that farmers' responses to climate stress are not uniform, even within the same subdistrict, and may reflect variation in access to resources, information and institutional support

Farmers in these villages do change the way they farm when they notice unusual rainfall or other climate signals, but the extent of these adjustments remains limited. In Kebonagung, by contrast, farmers are grouped as "less adaptive", as most continue to follow established routines and rarely adjust their management when the weather shifts. The fact that such differences appear within a single subdistrict indicates that adaptation is strongly shaped by local context, including water availability, infrastructure conditions, and the way farmers learn from one another

Adaptation profiles differ by strategy as well as by village. For advancing planting time, farmers in Selopamioro show a low level of adaptation because they depend entirely on rain-fed conditions and rarely start planting earlier than usual. Wukirsari farmers display a moderate level of early planting; some prepare seedlings as soon as they observe early signs of the rainy season, which allows them to shift planting dates slightly forward. In Kebonagung, the level of early planting adaptation is very low because farmers rely on a technical irrigation network and tend to maintain their regular planting calendar. This pattern indicates that access to irrigation can reduce incentives to adjust planting dates, since water availability is perceived as more stable than rainfall [6,8].

For delayed planting, Selopamioro farmers are highly adaptive. When rainfall is late or insufficient, they postpone planting to reduce the risk of crop failure, reflecting their dependence on direct rainfall. Farmers in Wukirsari show a moderate level of delay, as they combine rain-fed systems with pumps whose effectiveness declines during long droughts. Kebonagung farmers seldom delay planting because irrigation water remains available even when rainfall is low, enabling them to follow the usual schedule. Delayed planting thus appears as a key strategy in fully rain-fed systems but becomes less relevant where irrigation buffers the impact of rainfall variability [6,9].

The use of pranata mangsa is highest in Selopamioro. Many older farmers there continue to rely on this traditional seasonal calendar to determine planting time. In Wukirsari and Kebonagung, the use of pranata mangsa is moderate; farmers know the concept but combine it with considerations such as irrigation water, labour availability, and market demand. This pattern shows that traditional knowledge remains important in some communities, particularly where formal climate information is scarce, but is increasingly blended with other decision criteria [9,11].

Pump use as an adaptation measure is moderate in Selopamioro, low in Wukirsari, and almost absent in Kebonagung. In Selopamioro, a few farmers operate pumps to compensate for low rainfall during dry spells, but rising fuel prices and limited capital prevent broader use. In Wukirsari, the uptake of pumps is further limited by the distance to water sources and the expense of running the equipment. In Kebonagung, farmers depend on the existing irrigation network and therefore make little use of groundwater or river pumping This contrast underscores that promoting pump-based adaptation without considering local hydrology, energy costs, and farmers' financial capacity may not be effective [9,14].

Crop management and crop diversification are more widely practiced than some of the other strategies. Farmers in Wukirsari and Kebonagung show strong adaptation in crop management, consistently applying pesticides to control pests and diseases that become more severe under variable climate conditions. In Selopamioro, the level of pesticide use is moderate because some farmers follow organic practices and avoid chemical inputs. For crop diversification, farmers in Selopamioro and Wukirsari are more adaptive. During the dry season, they shift from rice to secondary crops such as chili, tobacco, peanuts, mung beans, soybeans, and maize. In Kebonagung, crop diversification remains limited and farmers are more specialised in rice production. In general, the evidence suggests that farmers are more willing to try new crops in areas where they can find good alternatives, get to reliable markets, and learn about crops other than rice. In contrast, places with reliable irrigation and a strong focus on rice farming tend to stay in a system where only one crop is grown [8,14].

3.3 Determinants of adaptation strategies and policy implications

The adaptation of Inpari Nutri Zinc rice farmers in Imogiri district, Bantul Regency, is influenced by several factors. The factors are analyzed using binary logistic regression analysis, with the Hosmer and Lemeshow Test employed to assess the empirical data and the model's goodness of fit. Below is an explanation of several factors that influence the

adaptation of Inpari Nutri Zinc rice farmers. The binary logistic regression models examine how socio-economic and farm characteristics influence the probability of adopting each of the six adaptation strategies. The goodness-of-fit statistics show that all models fit the data reasonably well. For all strategies, the Hosmer–Lemeshow tests give p-values greater than 0.05, and the estimated Chi-square values are less than the critical values.

Table 4 Goodness-of-fit statistics (Hosmer–Lemeshow test)

Adaptation	X^2 (Chi-square)	Df	P Value	-2log likehood	Nagelkerke R Square
Advance Planting Time (Y1)	5.756	8	0.675	119.042	0.131
Delayed Planting time (Y2)	5.677	8	0.683	128.625	0.172
Pranata Mangsa (Y3)	8.726	8	0.366	148.794	0.101
The Use of Pumps (Y4)	5.65	8	0.686	153.76	0.193
Crop Management (Y5)	2.079	8	0.978	80.154	0.22
Crop Diversification (Y6)	8.342	8	0.401	132.895	0.202

Table 4. This suggests both the observed and estimated probability values are not very different from each other, so all the adaptation strategies work well. Nagelkerke R^2 values range from about 0.10 (pranata mangsa) to 0.22 (crop management), which suggests that the selected socio-economic and farm-level variables explain a meaningful, though not exhaustive, share of the variation in farmers' adaptation decisions

Table 5. Logistic regression coefficients for adaptation strategies

Factors	Y1	Y2	Y3	Y4	Y5	Y6
Age	-0.036	-0.035	0.051	-0.023	**0.087***	-0.032
Last education	**-0.397***	**-0.498****	-0.187	**-0.373***	0.02	**-0.596****
Land area	0.816	**-1.089***	-0.12	**-1.357***	0.349	-0.303
Farming experience	0.014	0.016	**-0.042****	0.02	-0.006	-0.028
Number of family members	0.069	-0.037	-0.033	0.261	0.097	-0.098
Income	0.003	0.005	0	0.001	**-0.003***	0.003
Gender	-1.023	0.279	-0.525	-0.823	-0.945	**-1.447****
Search for weather information	0.681	0.189	-0.248	0.055	**-1.641****	0.458
Land status	-0.676	-0.346	0.199	-0.437	0	**-0.913***
Farmer Group Participation	-0.409	**-1.476***	-0.664	**-2.163***	-0.473	**-1.492***

Note: *Significance at the level of 10%; **Significance at the level of 5%; ***Significance at the level of 1%

Table 5 shows the coefficients that were estimated determined by the multiple binary logistic regression models. Table 6 shows the odds values for every adaptation strategy. The tables below illustrate the way socio-economic and farm-level factors affect the chances that farmers will use certain climate-smart practices. All models pass the Hosmer–Lemeshow goodness-of-fit test, and the Nagelkerke R^2 values indicate a moderate explanatory power, so the estimated effects can be interpreted with reasonable confidence

Table 6. Odds ratios for factors affecting adaptation strategies

Factors	Y1	Y2	Y3	Y4	Y5	Y6
Age	0.965	0.965	1.052	0.977	**1.09**	0.968
Last education	**0.673**	**0.608**	0.829	**0.689**	1.02	**0.566**
Land area	2.261	**0.337**	0.887	**0.257**	1.418	0.739
Farming experience	1.014	1.016	**0.959**	1.02	0.994	0.973
Number of family members	1.071	0.964	0.967	1.298	1.102	0.907
Income	1.003	1.005	1	1.001	**0.997**	1.003
Gender	0.359	1.322	0.592	0.439	0.389	**0.235**
Search weather information	1.975	1.208	0.78	1.056	**0.194**	1.58
Land status	0.509	0.708	1.22	0.646	1	**0.401**
Farmer Group Participation	0.664	**0.229**	0.515	**0.115**	0.623	**0.226**

Education stands out as a variable that consistently reduces the likelihood of adopting several strategies. Farmers with higher levels of schooling are less likely to advance or delay planting, use pumps, or diversify their crops (Y1, Y2, Y4, Y6). The negative signs of the coefficients in Table 5, together with odds ratios below 1 in Table 6, show that better-educated farmers make less use of these plot-level adjustment strategies. This pattern runs counter to the common expectation that education always enhances adaptive capacity In the study area, a plausible explanation is that more educated farmers have stronger links to non-farm employment or more stable income sources, which reduce their dependence on tactical on-farm adjustments and shift their focus towards livelihood diversification outside agriculture [12,14].

Land area also plays an important role in shaping adaptation behaviour. Larger landholdings significantly decrease the odds of delaying planting and using pumps (Y2 and Y4). The negative and significant coefficients in Table 5, combined with odds ratios well below 1 in Table 6, suggest that farmers with larger plots are less likely to shift their planting calendar or to rely on pumping as a response to rainfall deficits. For these farmers, reorganising operations over a wide area or providing enough pumped water can be costly and logistically difficult. By contrast, smallholders may find it easier to adjust planting dates and to operate pumps on limited plots, making these strategies more attractive under rainfall variability [9].

Age and experience have more nuanced effects. Age has a positive and significant coefficient only for crop management (Y5), with an odds ratio of about 1.09, meaning that each additional year of age increases the odds of strengthening pest and disease control by roughly 9% The findings indicate that older farmers, despite possible physical limitations, are more inclined to use management practices they already know and trust to shield their crops from climate-related pressures [12]. In contrast, longer farming experience shows a negative and significant relationship with the use of pranata mangsa (Y3). The odds ratio below 1 suggests that farmers with longer experience are less likely to depend solely on the traditional seasonal calendar and may combine it with other signals or informal information when making planting decisions. Overall, household size does not show a significant effect in any model, which implies that family labour availability is less critical than access to land, information, and other assets for the strategies considered [8]

Economic and institutional factors also influence adaptation in specific ways. Income shows a negative and significant association with crop management (Y5), and the odds ratio slightly below 1 suggests that farmers with higher incomes are less inclined to intensify pesticide use or similar management actions as their main response to climate stress[15]. For crop diversification (Y6), gender, land tenure, and farmer-group membership play an important role. Women farmers and those working on rented or sharecropped plots are much less likely to diversify their crops, as indicated by the negative coefficients and odds ratios below 1. This outcome points to barriers such as reduced decision-making power, shorter planning horizons, and more restricted access to credit, all of which can make it harder for women and tenants to adopt diversification as an adaptation strategy[10,15]. Farmer-group membership also shows a negative and significant relationship with delayed planting, pump use, and crop diversification (Y2, Y4, Y6), with odds ratios well below 1. In the current context, group membership appears to reinforce conventional schedules and practices rather than encourage experimentation, indicating that farmer organisations have not yet been fully reoriented towards learning and innovation in climate-smart adaptation [8,12]

In summary, Tables 5 and 6 show that Inpari Nutri Zinc farmers' adaptation is determined not only by climate exposure, but also by education, land area, income, experience, land status, gender, and the institutional dynamics of farmer groups. These findings support the argument that interventions to strengthen climate adaptation and sustain Inpari Nutri Zinc adoption need to combine technical support, institutional strengthening, and special attention to more vulnerable groups such as smallholder farmers, women, and tenants.

4 Conclusion

This study analysed how Inpari Nutri Zinc rice farmers in Imogiri Subdistrict respond to increasing climate variability and which factors shape the adoption of specific adaptation strategies. The results show that farmers in Wukirsari and Selopamioro achieve higher adaptation scores than those in Kebonagung, even though all three villages face similar shifts in rainfall and a drier planting season. Farmers combine several practices to cope with these conditions, including adjusting planting dates (advancing or delaying), using the pranata mangsa seasonal calendar, operating pumps during dry spells, strengthening crop management, and diversifying into non-rice crops. These patterns confirm that climate-smart adaptation is already taking place, but the overall intensity of response remains moderate and varies strongly across villages.

The regression analysis indicates that socio-economic, institutional, and farm-level characteristics jointly influence adaptation. Education, farm size, income level, farming experience, gender, land tenure, membership in farmer groups, and access to weather information each have a significant influence on the likelihood of adopting at least one of the six adaptation strategies, while household size shows no significant effect.

. Higher education and larger landholdings are associated with lower use of several field-level adjustments, suggesting that farmers with more schooling or larger plots may rely on alternative livelihood strategies or more stable irrigation, rather than tactical changes in planting and crop choice. Older farmers are more likely to reinforce crop management, while long experience reduces reliance on the pranata mangsa. Women, tenants, and sharecroppers have lower odds of diversifying crops, and farmer-group membership, in its current form, tends to reinforce conventional schedules rather than encourage experimentation.

These findings highlight the need to reorient extension and farmer-group activities towards climate-smart learning, trial, and information sharing, while giving specific attention to smallholders, women, and tenants who face greater constraints. Because Inpari Nutri Zinc is promoted as a biofortified variety in stunting-prone areas, sustaining its cultivation under changing climate conditions is essential for local food and nutrition security. Policies that

integrate climate information services, support low-cost adaptation options, and strengthen the adaptive role of farmer organisations can help maintain the uptake of Inpari Nutri Zinc and enhance the resilience of farming households in Bantul.

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References

1. K. Khampuang, B. Dell, N. Chaiwong, S. Lordkaew, H. Rouached, and C. Prom-u-thai, Grain Zinc and Yield Responses of Two Rice Varieties to Zinc Biofortification and Water Management. Sustainability (Switzerland). **14**, 14 (2022). https://doi.org/10.3390/su14148838
2. Rosanti, E. Damayanthi, and Z. Nasution, Development of Inpari IR Nutri Zinc Instant Rice: Physical Properties, Sensory Characteristics, and Nutrients Content. Malaysian Journal of Medicine and Health Sciences. **19**, S1 (2023)
3. E. Damayanthi, L. Nurjanah, and H. F. Navratilova, Zinc and Iron Content of Biofortified Rice Variety Inpari IR Nutri Zinc in *Malaysian Journal of Medicine and Health Sciences* (2023), pp. 137–138
4. F. Khairunnisa, L. Rahayu, Z. Rozaki, and C. W. Rubiyanto, The Impact of Inpari Nutri Zinc Rice on Farmer Welfare and Food Security in Stunting-Prone Bantul, Indonesia. Research on World Agricultural Economy. **6**, 2 (2025). https://doi.org/10.36956/rwae.v6i2.1644
5. R. M. Pujahari, S. P. Yadav, and R. Khan, Intelligent farming system through weather forecast support and crop production in *Application of Machine Learning in Agriculture* (Elsevier, 2022), pp. 113–130
6. A. Dissa, M. Slingerland, K. E. Giller, and K. Descheemaeker, Navigating seasonality in cotton-based farming systems in southern Mali. Climate Risk Management. **46**, (2024). https://doi.org/10.1016/j.crm.2024.100649
7. N. M. Lowe, A. G. Hall, M. R. Broadley, J. Foley, E. Boy, and Z. A. Bhutta, Preventing and Controlling Zinc Deficiency Across the Life Course: A Call to Action. Advances in Nutrition. **15**, 3 (2024). https://doi.org/10.1016/j.advnut.2024.100181
8. H. Le Dang, E. Li, I. Nuberg, and J. Bruwer, Factors influencing the adaptation of farmers in response to climate change: a review. Climate and Development. **11**, 9 (2019). https://doi.org/10.1080/17565529.2018.1562866
9. S. Singh, Farmers' perception of climate change and adaptation decisions: A micro-level evidence from Bundelkhand Region, India. Ecological Indicators. **116**, (2020). https://doi.org/https://doi.org/10.1016/j.ecolind.2020.106475
10. R. Henriksson, K. Vincent, E. Archer, and G. Jewitt, Understanding gender differences in availability, accessibility and use of climate information among smallholder farmers in Malawi. Climate and Development. **13**, 6 (2021). https://doi.org/10.1080/17565529.2020.1806777
11. Z. Guido, A. Zimmer, S. Lopus, C. Hannah, D. Gower, K. Waldman, N. Krell, J. Sheffield, K. Caylor, and T. Evans, Farmer forecasts: Impacts of seasonal rainfall expectations on agricultural decision-making in Sub-Saharan Africa. Climate Risk

Management. **30**, August 2019 (2020). https://doi.org/10.1016/j.crm.2020.100247

12. A. Cano and B. Castro Campos, Drivers of farmers' adaptive behavior to climate change: The 3F-SEC framework. Journal of Rural Studies. **109**, (2024). https://doi.org/10.1016/j.jrurstud.2024.103343
13. R. Lestari, A. Nurmandi, M. Younus, H. Lawelai, and W. Suardi, Optimizing Social Media Platforms to Foster Active Public Engagement in Tackling Climate Change and Environmental Conservation. Society. **13**, 1 (2025)
14. K. T. Thinda, A. A. Ogundeji, J. A. Belle, and T. O. Ojo, Determinants of Relevant Constraints Inhibiting Farmers' Adoption of Climate Change Adaptation Strategies in South Africa. Journal of Asian and African Studies. **56**, 3 (2021). https://doi.org/10.1177/0021909620934836
15. R. U. Onyeneke, M. U. Amadi, C. L. Njoku, and E. E. Osuji, Climate change perception and uptake of climate-smart agriculture in rice production in Ebonyi State, Nigeria. Atmosphere. **12**, 11 (2021)