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Climate change adaptation in red rice farming of Segreng and Inpari 24 varieties in Gunungkidul District, Yogyakarta, Indonesia

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Abstract. Climate change presents ongoing challenges for red rice farmers in Gunungkidul District. To overcome this challenge, climate-resistant red rice varieties, Segreng and Inpari 24, have been introduced to support local agriculture. This study investigates the adaptation strategies used by farmers to cultivate these varieties and examines the factors influencing their adaptation efforts. The research focused on Panggang Sub-district (Segreng variety) and Semin Sub-district (Inpari 24 variety), with a sample of 250 red rice farmers, consisting of 150 Inpari 24 farmers and 100 Segreng farmers. The analysis used was descriptive methods, scores, and Spearman rank correlation. The research results show a high level of adaptation to climate change in the Segreng rice farm and a medium level in the Inpari 24 rice farm. The main influencing factors are the farmer's age, land area, access to weather forecast information, and proximity to local markets. Access to weather forecast information particularly impacts Inpari 24 rice farming. Recommendations to the government include increasing accessibility to weather forecasts for local farmers and providing education, strategies, and resources for climate-smart agricultural practices. This includes efficient water management, soil conservation techniques, and drought-resistant seeds, ultimately increasing farmers' resilience to climate change.

1 Introduction

Gunungkidul District is a red rice germplasm with the superior local varieties Segreng Handayani and Mandel [1]. In 2018, the government developed a red rice innovation, namely, the Inpari 24 variety, an irrigated inbred rice variety that can be planted on dry land. Red rice of the Inpari 24 variety can produce 7.7-8 tons per hectare. This figure is greater than the productivity potential of the Segreng variety of red rice, which is 4.5 tons per hectare [2]

The red rice variety Inpari 24 is a biofortified rice [3]. Biofortification of rice through functional rice assembly aims to obtain high-yielding varieties with high yield potential that contain microelements, vitamins, and nutrients useful for health [4,5]. Red rice has a higher fibre content, which helps prevent heart disease [6]. Red rice also contains flavonoid

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compounds that protect against diabetes. In addition to fibre, the content of zinc, iron, magnesium, and red rice protein is also higher [7]

Several sub-districts in Gunungkidul District have experienced the impact of the prolonged dry season and high intensity and shorter rainy season. Climate change arises from alterations in climate variables, particularly those associated with human activities, such as temperature (air temperature), rainfall, air humidity, and wind patterns. These changes, in turn, reshape the global atmospheric composition and contribute to the evolution of natural climate variability across various periods [8]. Long periods of excessive rainfall and extended dry spells are consequences of climate change. Escalating climate change, characterised by prolonged droughts and extended rainy periods, significantly impacts cropping seasons and patterns. This, in turn, introduces uncertainties regarding planting times, productivity, and crop quality, and increases the risk of crop failure [9].

The productivity of upland rice in Gunungkidul District declined in 2018. This decrease can be attributed to the uncertain climatic conditions prevailing in Gunungkidul District, which can reduce soil fertility and consequently diminish red rice production. The decline in productivity may be linked to alterations in rainfall patterns, leading to shifts in the timing of the rainy and dry seasons. Such changes can increase the risk of crop failure [10]. Figure 1 illustrates the rainfall patterns in Gunung Kidul District from 2009 to 2021.

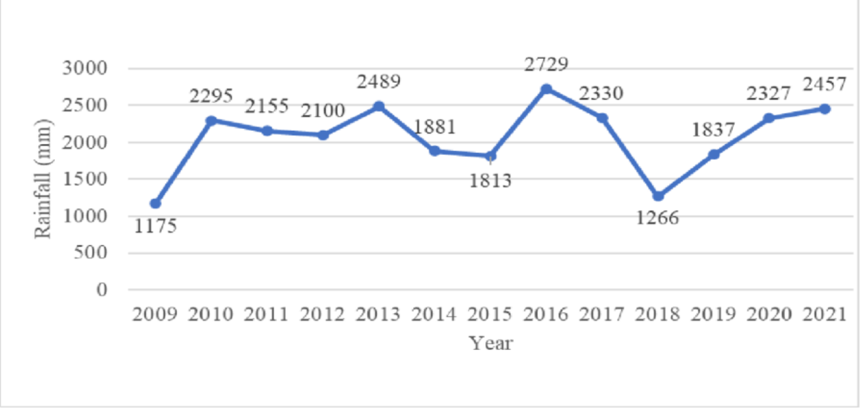

Fig. 1. Rainfall in Gunungkidul District in 2010-2020 (BPS Gunungkidul District, 2022).

The prolonged dry season experienced during 2017-2018 has significantly impacted the growth of red rice. This impact was primarily because the agricultural land utilised by red rice farmers in Gunungkidul District relies on rain-fed irrigation. The erratic climate changes that occur each year necessitate red rice farmers to adapt to the challenges of climate change. Uncertain climate changes every year make red rice farmers must be able to adapt to climate change. Adaptation represents a crucial policy choice concerning climate change that profoundly influences developmental endeavours. The policy referred to here is climate change policies encompass various strategies and actions aimed at addressing the challenges posed by climate change [11]

Farmers' adaptation to climate change will only occur under the influence of socio-economic, cultural, political, geographical, ecological, and institutional factors that shape the interaction between humans and their environment [12]. The sustainability of an adaptation depends on adaptive capacity, knowledge, skills, stability of life, resources, and institutions that can be accessed to practice an effective adaptation strategy [13]. In climate change, adaptive capacity is crucial for mitigating risks and minimising vulnerabilities, ensuring that individuals and communities can adapt to a changing climate without suffering significant adverse impacts. Environmental perception is one of the critical elements that influence the adoption of adaptation strategies. Previous research [14] shows that changing cropping patterns and shifting planting times are forms of adaptation that farmers do in dealing with climate change.

The main obstacle farmers experience in adapting to climate change are institutional factors. This enhances the accessibility, usability, and appropriateness of institutional services for climate adaptation. Among other benefits, this simplifies access to information about weather forecasts and advancements in agricultural technology [15]. However, the services currently available at the farm level must be improved to support an effective adaptation process. An understanding of adaptation can help formulate policies to respond to climate change so that the vulnerability of systems to impacts can be significantly reduced [16]. This study describes how red rice farmers adapt to climate change and what influences their adaptation. Ultimately, the goal should be to empower red rice farmers to build resilience to the impacts of climate change, ensuring that their livelihoods and well-being are protected in the face of shifting weather patterns and conditions.

2 Methodology

The area used to conduct this research was in Gunungkidul District, namely in the Semin Sub-district for the Inpari 24 variety and the Panggang Sub-district for the Segreng variety. Semin Sub-district is in the northern part (Batu Agung zone), which has an area of 78,92 km^2 with a height of approximately 400 meters above sea level. Panggang Sub-district, is in the south (Pegunungan Seribu zone), has an area of 9.980,4 hectares and has land with a high slope, causing difficulties for farmers in cultivating the land. Location determination was carried out using a purposive sampling technique, and two research locations were selected: Panggang Sub-district and Semin Sub-district. Panggang Sub-district exhibits the lowest red rice productivity at 3.84 tons/ha, while Semin Sub-district has successfully implemented the Inpari 24 variety, resulting in the highest increase in productivity at 5.16 tons/ha. The samples were clustered into two groups: Inpari 24 and Segreng. A total of 250 farmers were included in the selection, with 150 from Semin Sub-district and the remaining 100 from Panggang Sub-district. Descriptive analysis was used to describe the variables in the study.

Table 1. Operational definition of variables and their measurement.

Variables	Description	Data type	References
Gender	Gender is the division between male (1) and female (0)	Nominal	[17,18,19]
Age	Age of the farmer (years)	Ratio	[19,18,20]
Education	The level of formal education the farmer has taken: 1. no education 2. elementary 3. secondary education 4. higher education 5. undergraduate	Ordinal	[21,15,22,11]
Farming experience	Farmers' experience in cultivating red rice	Ratio	[23,24,15]
Land ownership status	Land owned by the farmers or taken on rent	Nominal	[25,26,18]
Land size	The total cultivated land owned by the farmer, measured (m^2)	Continuous	[18,19]
Number of family members	Total number of family members	Continuous	[27,17,18]
The looking for weather forecast information.	Farmer behaviour to obtain information about climate	Binary (1,0)	[18,28]
Distance from the local market.	The distance from the farmer's residence to the local market (km)	Continuous	[29,30]

The assessment of farmers' responses to climate change in the Panggang and Semin Sub-districts can be seen from the adaptation activities of brown rice farmers to red rice farming of the Segreng variety and agriculture of the Inpari 24 variety using score analysis. The assessment of how farmers adapt to changes in crop cultivation is categorised into four benchmarks. These benchmarks include "Not Doing" (ND), indicating that farmers do not adapt during the long dry season; "Rarely Doing" (RD), signifying that farmers infrequently adapt, typically once or twice; "Doing" (D), indicating that farmers carry out adaptation measures at specific times; and "Always Doing" (AD), denoting that farmers consistently implement regular adaptation strategies. (Table 2).

Table 2. Adaptation of red rice farmers to the process of crop cultivation.

Adaptation activities	Score range			
	1	2	3	4
Application of intercropping planting system	ND	RD	D	AD
Arrangement of cultivating the land	ND	RD	D	AD
Immediately plant in rainfed rice fields at the beginning of the rainy season.	ND	RD	D	AD
Do not plant anything during the extended dry season	ND	RD	D	AD
Seed selection	ND	RD	D	AD
Using dry-resistant varieties	ND	RD	D	AD
Pesticide use	ND	RD	D	AD
Increased intensity of weeding	ND	RD	D	AD

The total adaptation categories carried out by farmers were used as score intervals, as shown in Table 2. The score intervals are as follows: a) Not adaptive: This category applies when local farmers do not take action to adapt to climate change on their farms; b) Less adaptive: This category is assigned when local farmers do not respond to climate change, which may impact their farming, and they infrequently adjust their behaviours; c) Moderately adaptive: This category is relevant when local farmers respond to climate changes that affect their farming; however, it is common for them to adapt to various climate changes;, d) Adaptive: This category is appropriate when local farmers respond and apply behavioural adaptations or habitual patterns to address the impacts of climate change without careful consideration; e) Highly adaptive: This category is assigned when local farmers respond and apply behavioural adaptations or habitual patterns with careful consideration to address the impacts of climate change. This can help minimise the risk of poor outcomes.

Table 3. Adaptation score interval.

Category	Score adaptation
Not adaptive	8.0 – 12.8
Low adaptive	12.9 – 17.6
Moderately adaptive	17.7 – 22.4
Adaptive	22.5 – 27.2
Highly adaptive	27.3 – 32.0
Maximum score	32
Minimum score	8
Interval	4.8

Spearman rank correlation analysis assesses the relationship between various factors, including gender, age, education, farming experience, land ownership status, land size, number of family members, the search for weather forecast information, and distance from the local market. These factors affect the level of adaptation among farmers during the long, dry seasons.

$$r_s = 1 - \frac{6\sum {d_i}^2}{n(n^2-1)} \quad (1)$$

where r_s is the Spearman correlation coefficient, di is the difference in score between two variables, and n is the number of data or samples.

3 Results and discussion

3.1. Adaptation of farmers to the process of cultivating crops

Red rice farmers in the Panggang and Semin sub-districts need to adapt to climate change to survive. This adaptation is carried out so that the farming business is maintained and farmers can adjust to an uncertain and frequently changing climate. Farmers' adaptation to climate change depends on several aspects, such as farmers' adaptive abilities or capacities, economic stability, farmer skills, resource availability families, and the availability of institutions that support the implementation of effective and efficient farmer adaptation strategies [16,31]

The primary issue when entering the planting season from July to November (dry season) is challenging. This season is notably susceptible to drought due to the lack of spring facilities, which compels farmers to implement climate adaptation strategies to safeguard their productivity and income from declining.

Table 4. Differences in the characteristics of Inpari 24 and Segreng red rice.

Description	Inpari 24	Segreng
Grain form	Slender	Slender
Fallen	Not easy to fall	Not easy to fall
Grain loss	Not easy to fall out	Easy to fall out
Potential results	7,7 tons/hectare	5,4 tons/hectare
Average potential	6,7 tons/hectare	3,5 – 5,0 tons/ hectare
Grain weight 1,000 grains	26 grams	24,33 grams
Rice colour	Red	Red
Grain colour	Yellow	Reddish yellow
Rice texture	Fluffier	A little hard
Pest resistant	Leafhoppers and blight	Leafhoppers
Plant height	106 cm	95 cm
Plant age	111 days	100 days

Farmers choose to grow high-yielding varieties that are drought-resistant or water-resistant and have low greenhouse gas emissions. Farmers cultivate a type of drought-resistant rice variety in rainfed rice fields, namely the Segreng variety. As shown in Table 4, the yield potential and average potential of the red rice variety Inpari 24 were higher than those of the red rice variety Segreng. However, the Segreng rice variety is harvested faster than Inpari 24. The weakness of the Segreng variety is that the grain falls off quickly, and the texture of the rice could be more accessible. Red rice variety Inpari 24 texture of fluffier rice

Farmers engage in adaptive red rice farming activities to achieve maximum production. These activities include implementing cropping systems, intercropping to obtain a variety of results, cultivating the soil to maintain its fertility for future planting, planting rice at the beginning of the rainy season, avoiding planting altogether to prevent crop failure, preparing high-quality seeds or seedlings, using drought-resistant rice varieties, applying biological and chemical pesticides to eliminate pests that can cause crop failure, and intensifying weeding to prevent yield loss.

Table 5. The results of farmers' adaptation average score on red rice farming of the Segreng variety and Inpari 24 variety.

Adaptation activities	Segreng variety		Inpari 24 variety	
	Score	Category	Score	Category
Intercropping system	3.23	High	2.53	Moderate
Arrangement of cultivating the land	3.44	Very high	2.99	
Planting the beginning of the rainy season	3.89	Very high	3.73	Very high
Not planting	2.78	Moderate	2.49	Moderate
Seed selection	2.86	High	2.23	Moderate
Using dry-resistant varieties	2.92	High	2.29	Moderate
Pesticide use	2.21	Moderate	2.73	Moderate
increased intensity of weeding	3.24	High	3.05	High
Total score	24.57		22.03	
Criterion	Adaptive		Moderate Adaptive	

*) Each adaptation activity has a score range of 1-4
Very low: 1-1.60: Low; 1.61-2.20: Moderate: 2.21-2.80; High :2.81-.3.40; Very high:3.41-4.00

Based on Table 5 for adaptation score categories, the red rice farming of the Segreng variety is classified as adaptive. In contrast, the red rice farming of the Inpari 24 variety is moderate. This category is seen from the results of the score obtained for each adaptation question. Knowledge about adaptation to increasing red rice production in Panggang Sub-district is included in the high category. It can be said that farmers in Panggang Sub-district are more able to adapt to climate change, as seen from the high level of adaptation to climate change. Adaptation compared to red rice cultivation. Inpari 24 fell under the moderate category. This is due to the novelty of the Inpari 24 red rice variety, leading farmers to abstain from engaging in adaptation activities.

Farmers must adapt to climate change in red rice farming of the Segreng and Inpari 24 varieties to get maximum results. Figure 2 shows the percentage of farmers who adopted intercropping, soil management, early planting, no planting, careful seed preparation, drought-resistant rice varieties, pesticide use, and increased weeding intensity. The percentage of farmers who frequently practice the intercropping system in Panggang Sub-district and Semin Sub-district is higher than those who never or rarely do it. By applying the intercropping cropping system, the yields obtained by farmers were much more numerous and varied. Changing climate and weather conditions and frequent droughts have forced red rice farmers to apply intercropping cropping systems to minimise the potential for crop failure and yield losses.

Regulating land management is one of the adaptation activities carried out by red rice farmers in dealing with climate change. This is because the land owned by farmers in the two sub-districts is rain-fed land, which tends to experience frequent droughts, which means that the land must be cultivated for farming. This activity is carried out by farmers in the two sub-districts so that they can still plant under any condition to avoid crop failure or reduced yields.

Planting at the beginning of the rainy season is mainly done by red rice farmers in Panggang and Semin Sub-districts. Farmers choose this activity to get enough water to grow crops. Carrying out planting activities at the beginning of the rainy season is very good for fertility and yields to get maximum results. People in Gunungkidul District rely only on rainwater as a source of water for their agricultural land. This means that red rice farmers in Gunungkidul District must know about weather forecast information to estimate planting time. Some old farmers calculate planting time using Javanese calculations, commonly known by the surrounding community as *titen* science (*pranoto mongso*).

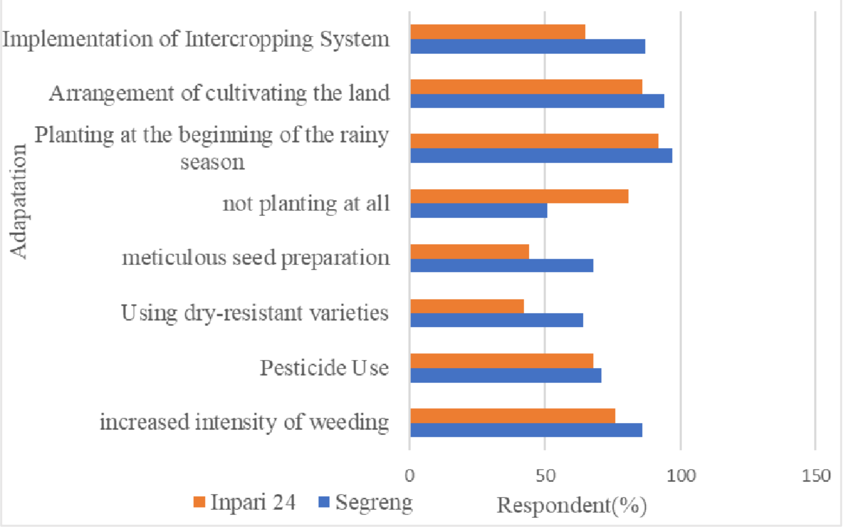

Fig. 2. Adaptations made by Inpari 24 and Segreng farmers.

Farmers in Gunungkidul District face the challenge of adapting to the changing climatic conditions in their region. Due to the dry land conditions in Panggang Sub-district, red rice farmers of the Segreng variety choose not to plant crops at all to avoid the risk of crop failure. This is in contrast to farmers in the Semin Sub-district, who plant more often, using the Inpari 24 variety. During climate and weather changes, farmers often refrain from planting crops to minimise the risk of crop failure. During the planting season, red rice farmers in Gunungkidul District typically opt to grow other crops, such as corn and cassava, in the same land areas where red rice was traditionally cultivated.

Careful seed preparation is performed by farmers to prepare for planting. Seed selection can reduce the risk of bad seeds at planting [32]. Most of the red rice farmers of the Segreng variety in Panggang Sub-district use drought-resistant seed varieties because farmers realise that their land is arid and must use drought-resistant rice varieties to still plant during the dry season. The percentage of red rice farmers of the Inpari 24 variety in Semin Sub-district who use dry-resistant rice varieties tends to do this only if the Inpari 24 rice variety is drought-resistant and planthopper-resistant.

Red rice farmers of the Segreng and Inpari 24 varieties mostly use pesticides to eradicate pests and minimise the risk of crop failure and yield losses. This means that most farmers have been able to adapt to the use of pesticides for the sustainability of red rice farming. Red rice farmers of the Segreng and Inpari 24 varieties often do and even always do weeding. This is done because many wild plants grow around the red rice farmer's land area, and the farmers know that weeds are essential to keep the plants produced healthy.

3.2. The relationship of factors influencing farmer adaptation

In this study, factors affecting farmers' adaptation included gender, age, education level, farming experience, land ownership status, land area, number of family members, seeking weather forecast information, and distance from the local market. These factors can influence climate change adaptation in Segreng's variety of red rice farming in the Panggang Sub-district and Inpari's 24 red rice farming in the Semin Sub-district.

Table 6. Characteristics of red rice farmers in Gunungkidul District.

	Segreng variety		Inpari 24 variety	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	52	52.00	95	63.33
Female	48	48.00	55	36.67
Age (years)				
26-37	16	16.00	1	0.67
38-49	32	32.00	28	18.67
50-61	45	45.00	79	52.67
62-73	7	7.00	35	23.33
74-85	0	0.00	7	4.67
Education level				
Not school	10	10.00	4	2.67
SD	53	53.00	93	62
SMP	28	28.00	36	24
SMA	9	9.00	17	11.33
Farming expérience (years)				
2–13	20	20.00	10	6.67
14–25	35	35.00	34	22.67
26–37	31	31.00	51	34.00
38–49	9	9.00	39	26.00
50–62	5	5.00	16	10.66
Number of family members				
0-4	49	49.00	143	95.33
5-9	51	51.00	7	4.67
Land tenure status				
Own	99	99.00	125	83.33
Revenue share/rent	1	1.00	25	16.67
Land size (m^2)				
1-100	12	12.00	1	0.67
101-300	65	65.00	22	14.67
301-600	16	16.00	36	24.00
601-1000	2	2.00	38	25.33
>1001	5	5.00	53	35.33
The looking for weather forecast information				
Never did	25	25.00	68	45.33
Do	75	75.00	82	54.67
Distance to market (km)				
1.80 – 6.55	40	40.00	140	93.33
6.56 – 11.3	60	60.00	10	6.67

Shifts in rain patterns affect agricultural resources and infrastructure, shifting park times, seasons, and planting patterns. Determination of planting time based on water availability aims to reduce the risk of crop failure and improve water use efficiency. Climate change will encourage farmers to change growing patterns to minimise the risk of crop failure, decrease yields, and reduce the quality of their crops [33,34]. The factors that are thought to have a relationship with farmers' adaptation to planting patterns include gender, age, education level, farming experience, land ownership status, land area, number of family members, looking for weather forecast information, and distance from the local market [15,35,36].

Rs is Spearman rank correlation, X1 is gender, X2 is age, X3 is education, X4 is farming experience, X5 is land ownership status, X6 is land size, X7 number of family members, X8 is looking for weather forecast information, and X9 distance from the local market.

Table 7. Spearman rank correlation analysis of the relationship between farmers' adaptation to red rice farming of the Segreng variety and Inpari 24 variety with the factors that influence.

Factors	Segreng variety			Inpari 24 variety		
	Rs	Sig	Relationship	Rs	Sig	Relationship
X1	0.096	0.343	Low	-0.039	0.639	Low
X2	0.258***	0.010	Moderate	-0.039	0.636	Low
X3	-0.098	0.334	Low	0.107	0.193	Low
X4	0.134	0.184	Low	-0.123	0.135	Low
X5	-0.145	0.150	Low	-0.103	0.211	Low
X6	0.202**	0.044	Moderate	-0.023	0.782	Low
X7	-0.006	0.950	Low	0.036	0.660	Low
X8	0.192*	0.056	Low	0.216***	0.008	Moderate
X9	0.310***	0.002	Moderate	0.079	0.337	Low

Based on the analysis results in Table 7, it is known that the relationship of farmers' adaptation to planting patterns in The Panggang Sub-district is influenced by factors such as age, land area, and distance from the local market. When the coefficient is positive or has a unidirectional relationship, the farmer is better able to adapt.

Differences in household characteristics headed by males and females will result in gaps in climate change adaptation. The results showed that gender has no effect on climate change adaptation, but there is a tendency for male farmers to be more adaptive to climate change [15,37]. Farmers with higher age levels tend to have more extended farming experience, so knowledge of the initial planting estimate is higher, meaning that farmers with a high age level of adaptation to their planting patterns are also higher. Old age factors also affect the acceptance of transformation that is not maximal. According to Aryal et al. [37], the higher the age of farmers, the more inefficient is the farm.

The level of education is the human demand to do and fill a life that can be used to obtain information to improve the quality of life. The higher one's education, the easier it will be to receive news, enhance the quality of life and expand science. Education significantly affects farmers' willingness to pay for climate change adaptation costs [38]. The higher the education of a farmer, the higher the awareness to maintain and care for nature most effectively and efficiently, so as not to leave a negative impact in the future. Farming experience is an incident that a farmer has experienced while cultivating crops. Farmers possessing substantial farming experience tend to exhibit heightened awareness of past climate occurrences, enhancing their capacity to evaluate and implement practical farm adaptations in response to extreme weather events. Based on research conducted by Abid et al. [15], the positive coefficient associated with years of farming experience in most adaptive actions signifies a direct correlation between farming experience and the likelihood of adapting to climate change.

Land ownership status can be seen as the farmer's land belonging to himself or the tenant. The negative coefficients observed for rental rates across most adaptation measures imply that tenants are generally more inclined to adapt their farms to perceived climate change than self-operating farmers (owners) [15]. Tenants' heightened propensity for adaptation may stem from their heightened awareness of farm income compared to landlords. Tenants, who must pay land rent, are more driven to adapt to climate change to maintain their gross income above total costs, a motivation that may be less pronounced among landlords [36].

The land area has a significant effect because farmers with a larger land area will be better able to adapt to planting patterns because they can use their land to grow crops with an intercropping system to get maximum yields. Another positive influencing factor is distance from the local market. Farmers far from the local market tend to prepare for planting material needs early because of their extended access [35].

Farmers' actions to seek weather forecasting information increase the possibility of adapting to climate change [15]. For red rice farmers of the Inpari 24 variety in Semin Sub-district, adaptation to climate change is influenced by the factor of seeking weather forecast information, where their high curiosity regarding weather forecast information and the ease of obtaining information because, in Semin Sub-district, the farmer groups are more active in participating in counselling. In addition, access to the network of red rice farmers of the Inpari 24 variety in the Semin Sub-district is more accessible than that of the Segreng variety in the Panggang Sub-district.

4 Conclusions and policy recommendations

The adaptation of Segreng red rice farmers to climate change is in the high category, whereas Inpari 24 variety rice farming is in the medium category. Adaptations that are often made by red rice farmers of the Segreng variety and Inpari 24 rice farmers related to climate change are the application of intercropping cropping systems, arrangements in soil management, planting early in the rainy season, preparing good and careful seeds, using drought-resistant rice varieties, and increasing the intensity of weeding.

Factors that affect the adaptation of red rice farming to climate change are age, land area, the need to find weather forecast information, and distance from the local market. Governments should prioritise increasing local farmers' access to weather forecasts and offering comprehensive education, strategies, and resources to encourage climate-resilient agricultural practices. This includes implementing efficient water management techniques, soil conservation methods, and the distribution of drought-resistant seeds to increase farmers' resilience to climate change. Suggested government actions include enhancing red rice farmers' access to weather forecasting information in Gunungkidul District and providing guidance and strategies related to climate change. These steps will enable farmers to develop more effective approaches to adapt to the ever-changing climatic conditions on their farms.

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