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ADAPTATION TO CLIMATE CHANGE DONE BY FARMERS AT AROUND THE DAM FOR FOOD SECURITY IN BOJONEGORO, INDONESIA

Rahayu Relawati[1*], M. Zul Mazwan[2], Bambang Yudi Ariadi[3], Sona Minasyan[4]
[1,2,3]Department of Agribusiness, Faculty of Agriculture and Animal Science, Universitas Muhammadiyah Malang, Jalan Raya, Indonesia.
[4]Department of Social Work, Faculty of Educational Psychology and Sociology, Armenian State Pedagogical University (ASPU), Armenia
[*]Corresponding author: rahayurelawati@umm.ac.id

Abstract
Climate change has caused uncertainty of weather. It also threatens the household food security of farmers around the dam. The study purposed to determine: 1) the perception of climate change; 2) the farmers' adaptation to climate change; 3) the factors affecting household food sufficiency in the climate change situation. The study was conducted at the Village Kedung Sumber, Bojonegoro Regency, Indonesia. The main data were obtained by interviewing the farmers' families. Descriptive analysis and the structural equation model were used to analyze the data. The results showed that most farmers cultivated crops on the dam when the water is receding. The main crops cultivated were corn, chili, watermelon, and rice. Most farmers' perceptions about climate change were the uncertainty of the weather, so it was hard to predict when the dam water is tidal or receding. In the climate change situation, farm production has decreased by an average of 20.9%. Some rice farmers even failed to harvest, and they switched to tobacco. Their efforts to adapt to climate change were changing the crops and starting cultivation earlier to avoid the dam from sudden floods. Their farm production and income were not enough for their food sufficiency. It needs support from the non-farming income. The SEM results showed that the climate significantly affected farm production. Afterwards, farm production and non-farm income positively determined the food sufficiency. It was still dominated by carbohydrates, vegetables, and vegetable protein. The recommendation given is the assistance to farmers in adapting climate change.
Key words: climate change, consumption, food security, food sufficiency.

RESEARCH BACKGROUND

Many nations face the problem of food insecurity, mainly for the poor society and the area of marginal land. Indonesia also faces the same issue. At the national level, domestic food production and distribution from imported food may be sufficient for all overpopulation. However, it does not mean that there is no food insufficiency problem.

Food insecurity at the household level is one problem that arises in all countries [1]. Several factors such as social, economic, political, demographic, natural, and livelihood caused the vulnerability of household food security [2]. Food security in all over the world is at risk due to climate change [3]. Climate change can reduce crop yields and cause drought in many areas so that cultivation of some crops cannot be carried out, or experience crop failure [4]–[8].

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Indonesia has a large risk of climate change, since its complex topography and diverse social conditions. On the other hand, population growth has an impact on increasing food demand [9], [10]. The most suitable commodities are rice, corn, chili, potatoes, vegetables [1], [7], [8]. All of these plants need rainfall, temperature, and humidity during their growing period. Climate change in agriculture can lead to uncertainty in temperature and rainfall, which is likely to have a negative impact on agricultural production [3]. It threatens household income and the sustainability of the rural economy [11]–[13]. Some crops farming in Indonesia are not adaptable to climate change, such as rice farming in Jambi, Indonesia was less sustainable in multidimensional to farm food security and climate change [14].

Many previous types of research studied the farmers' adaptation to climate change. Migration was one of the adaptation strategies to cope with climate change [15]. Climate change also warming, reducing agricultural productivity [4] and threatening food security. Farmers in Nepal adapted to climate change with adaptation technologies by the size of landholding and perceived threat of climate change to food security, the non-farm income [16], and threatening food security [17].

Five adaptive strategies are leading to a resilient livelihood, namely: self-evaluation, diversity dependency, storage and reserve, cooperation, and mobility over space and time [18]. It needs to be recognized that the effects of climate change on agriculture will be most severe for poor families and small scale farmers with minimal adaptive capacity [19]. The smallholder farmer needed extension services in adapting the climate change [20]. Moreover, the adaptation to climate change requires planning to anticipate the impacts on food security of the rural communities [21].

Research on the impact of climate change on agriculture especially at the micro-level is also very important, especially in the adaptation of farmers. However, there are only a few researches in Indonesia about the adaptation of farm households to climate change. To fill these knowledge gaps, it is necessary to understand the farmers' perception of climate change and how they adapt.

The focus of this study was on farmers around Pacal Dam in Bojonegoro, Indonesia, who are very vulnerable to climate change and have a low adaptation. The local farmers' land was around the mostly rain-fed dam, and during the rainy season, it was very susceptible to floods. Agricultural production in the study often experiences harvest failure. The type of agriculture there was a small-scale subsistence with average land ownership of less than 0.5 ha.

This agricultural sector contributes 13.41% of Indonesia's GDP [22], and absorbed labor from 41.3% of the population in Bojonegoro Regency [23]. The effects of

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climate change including an increase in temperature and erratic rainfall will have an impact on planting and food security [24]–[26]. Although there have been many similar studies, this research has contributed to adaptation strategies to climate change in agricultural areas which are prone to floods. The study purposed to determine: 1) the farmers' perception of climate change; 2) the farmers' adaptation on climate change, and 3) the factors affecting household food security in the climate change situation.

RESEARCH METHODS

A primary survey was conducted of 184 farmer households at Desa Kedung Sumber, districts of Temayang, Bojonegoro Regency, East Java Province, Indonesia. Primary data were obtained with a questionnaire that was recorded from the farmers' household condition. Farmers' perceptions of climate change were investigated descriptively. The effect of climate change and demographic on farming, and the effect of farming and non-farming income on household food security was evaluated using the SEM (Structural Equation Modeling). The latent variables and indicators of the SEM model are mentioned in Table 1.

Table 1. The latent variables and indicators of the SEM model

No.	Latent variables	Indicators	Measurement
1	Climate change	Decrease farm production	Likert scale: 1 – 5
		Decrease farm income	
2	Demography	The farmer's age	age (years)
		The number of family member	persons
3	Farming	Farming production for family consumption	Likert scale: 1 – 5
		Consumption crops	
		Farming income for family consumption	
4	Non-farm income	Income from farm labor for food consumption	Likert scale: 1 – 5
		Income from non farm labor for food consumption	
5	Food security	Sufficiency of carbohydrate	Likert scale: 1 – 5
		Sufficiency of animal protein	
		Sufficiency of vegetable protein	

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	Sufficiency of vegetables
	Sufficiency of fruits
	Sufficiency of milk
	Sufficiency of others food

RESULTS AND DISCUSSION

The farmer household characteristics

Table 2 mentions farming distribution based on crops, farm areas, and farm income. Most farmers cultivated crops on the dam when the dam was dry. The main crops cultivated were chilies, corn, tobacco, and rice. Their farm area was ranging from a minimum of 0.1 up to 3.5 Ha (hectare), on the average was 0.54 Ha. The percentage of households with less than 0.5 hectares of land was 57.2% (Table 2). As a comparison, the percentage of households in East Java Province who had the land area less than 0.5 Ha was 79% [22]. Meanwhile, the farm income per season (four-months) was ranging from Rp2,000,000 up to 40,000,000, on average was Rp5,744,178. As a comparison, the current exchange rate of the Rupiah in July 2020 was Rp14.853/USD [27].

Table 2. Farmer distribution based on crops, land area, and farm income

Farm characteristics	% Farmer
Crops	
Chili	0.29
Corn	0.25
Tobacco	0.22
Rice	0.14
Others	0.10
Land area (ha)	
<= 0.25	32.3
>0.25 - 0.5	24.9
>0.5 - 0.75	3.7
>0.75 - 1.0	28.6
>1.0	10.6
Farm income (Rp/season)	
<= 5,000,000	56.5
5,001,000 –10,000,000	29.4

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10,001,000 – 15,000,000	5.4
15,001,000 – 20,000,000	2.7
>20,000,000	6.0

Source: processed primary data, 2020

The farmers' perception on climate change

Most farmers' perceptions about climate change were the uncertainty of the weather, so it was hard to predict when the dam is dry or flooded. In previous years, the most rainfall occurred in November-December, so that the flash floods that always hit some villages usually occurred in November-December. During the flood, the dam was full, so farmers cannot grow crops around the dam. However, when this research was conducted at the end of 2019 there had not flooded yet, it happened in January 2020. In the climate change situation, the most rainfall was unpredictable [28]–[31]. So that farmers around the dam had difficulty in determining the planting and harvesting time, and they felt the negative impact of the high rains that came suddenly. This result was consistent with the previous finding [3].

On line with that, farmers felt the hotter temperature so they felt uncomfortable to work in the field. The increase in temperature would increase the need of water to plant due to high evapo-transpiration. The result was the problem of water scarcity and food production [32]. In general, the farmers agreed that the increase of temperature over a long period of time caused drought that damaged land and nature.

The next perception of climate change was the decrease in farm production. The erratic weather and rainfall patterns had an impact on decreasing agricultural production of farmers around the dam, because it had an impact on the plant nutritional intake [33]. When the production decreased, later it affected decreasing farm income [34]. The result showed that there was 28.3% decrease of production. The finding was consistent with [32] that agricultural production in developing countries can decrease due to climate change between 10% and 25%, even agricultural production in India can fall by 40%. Table 3 shows the detailed farmers' perception of climate change.

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Table 3. The farmers' perception of climate change

No	Perception	Number of farmer	%
1	Uncertainty of weather and hotter temperature	82	44.5
2	Decreasing farm production	52	28.3
3	Drought and difficulty of clean water	21	11.4
4	Need adaptation, have to change the crops	3	1.6
5	Extreme weather, floods, and windy	4	2.2
6	Uncertainty of the output price	4	2.2
7	Difficulty for farmers	10	5.4
8	No problem	8	4.3
	Total	184	100

Source: processed primary data, 2020

As many as 95.4% percent of farmers felt changes in climate conditions today compared to 5-10 years ago. They can recognize large changes in the uncertainty of weather and hotter temperature, drought and difficulty of clean water, decreasing farm production, needing adaptation, having to change the crops, extreme weather, being flooded and windy, uncertainty of the output price, difficulty for farmers. This was in line with the research result found by [12], [25], [35]–[37].

Adaptation to climate change

In the climate change situation, farm production has decreased by an average of 20.9%. Rice production has the largest decline, namely 31.5%. Some rice farmers even failed to harvest, and they switched to tobacco farming. Chili plants could relatively survive in the condition of climate change in the village. Their adaptation efforts to climate change included: 1) starting planting earlier to avoid a sudden full dam; 2) changing the crops; 3) seeking the additional income other than agriculture. These results were consistent with the previous research [8], [38], [39]. The adaptation strategies through non-agricultural income sources were also important and became an effective strategies [13], [40], [41].

If the farmers estimate flash floods and the dam would be full in November, they can start cultivating the crops by July, and by then, the dam could be full of the harvested plants. This is a form of an adaptation done by farmers, namely planting crops earlier to avoid floods that come suddenly. If there were no floods, chilies could be harvested for a longer period. Therefore, chili farmers can relatively survive in the climate change situation. Due to these various obstacles, many vegetable farmers have switched to chili planting. For the rice field, the climate change situation causes

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warmer temperatures and drier land, so the decline in rice production could be very drastic. Therefore, many rice farmers switched to tobacco planting as the alternative. This was also one of the adaptations to climate change done by farmers in Bojonegoro.

Previously, the farm production and income were not enough for the food security of the farmers' families. It needed support from the non-farming income. Therefore, when the dam was full of water, the farmer's family members worked off-farm. They worked as masons, carpenters, or motorcycle taxi riders. This was the third way of adapting to climate change.

The factors affecting household food security at the climate change situation

The SEM model fit is expressed by some indices as mentioned in Table 4. All indices show the appropriate model to explain the factors affecting food security. The APC has a p value < 0.001, which means that the error is less than 1 %. The AARS shows the ability of the model in explaining the variation of the independent latent variables to the variation of food security. The AVIF also fulfills the ideal criteria, which means that the model is free from the multicollinearity. It means that there is no correlation between the independent latent variables, both in block collinearity and full collinearity. All criteria show that the SEM model fulfills the goodness of fit so that the model is valid to determine the factors affecting food security.

Table 4. Model fit and quality indices

Quality indices	Result	Criteria	
Average path coefficient (APC)	0.252	P<0.001	
Average adjusted R-squared (AARS)	0.159	P=0.014	
Average block VIF (AVIF)	1.029	acceptable if <= 5	ideally <= 3.3
Average full collinearity VIF (AFVIF)	1.104	acceptable if <= 5	ideally <= 3.3

Source: Analyzed primary data, 2020.

The SEM results show that the climate significantly affected farm production. Also, farm production and non-farm income positively determine the food security (Fig.1). Climate and demographics have a positive effect on on-farm production. The latent variables of climate and demographic had a significant level of 1% and 5%, respectively. Furthermore, farming production become a mediate variable of climate and demographics in influencing food security, significantly, error of <1%. Food security is also affected by non-agricultural income with a 10% error rate.

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The path coefficient value indicates the effect of each independent variable on the dependent variable (Table 5). Each path coefficient has a p-value that indicates the error level of the estimated effect.

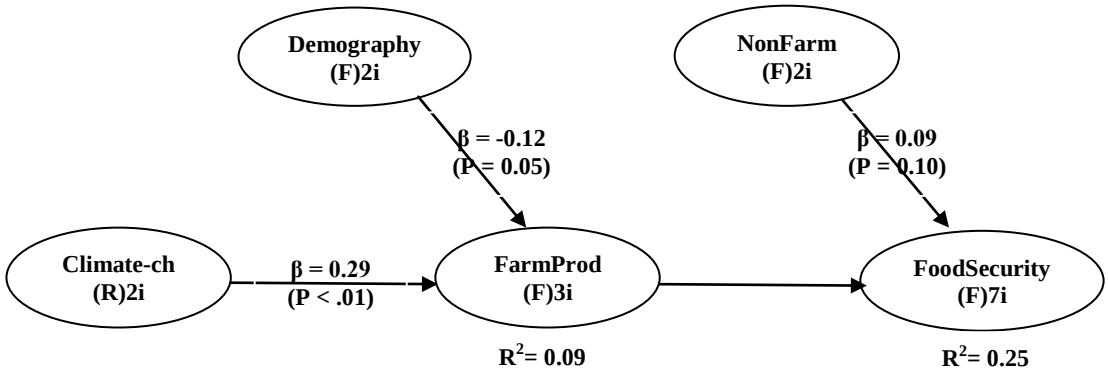

Figure 1. The SEM Model of factors affecting food security

Table 5. Path coefficients and p values

	Climate	Demography	Farming	Non-Farm income
Farm production	0.288 (<0.001)	-0.116 (0.054)		
Food Security			0.472 (<0.001)	0.094 (0.097)

Source: Analyzed primary data, 2020.

Table 6. The factor loading and the average score of each indicator

No.	Latent variables	Indicators	Factor loading	Average score
1	Climate change	Decrease farm production	0.986	3.9
		Decrease farm income	0.967	4.0
2	Demography	Farmer's age	0.961	46.1
		Number of family member	0.985	4
3	Farming	Farming production for family consumption	0.948	3.9
		Consumption crops	0.891	3.9
		Farming income for family consumption	0.905	4.0

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4	Non-farm income	Income from farm labor for food consumption	0.976	3.9
		Income from non farm labor for food consumption	0.967	3.9
5	Food security	Sufficiency of carbohydrate	0.818	4.3
		Sufficiency of animal protein	0.871	3.9
		Sufficiency of vegetable protein	0.922	4.1
		Sufficiency of vegetables	0.906	4.1
		Sufficiency of fruits	0.900	3.4
		Sufficiency of milk	0.931	3.3
		Sufficiency of others food	0.855	3.8

Source: Analyzed primary data, 2020.

The biggest path coefficient is on the effect of farming on food security, 0.472 with p-value <0.001. The farming is essential to fulfill the household food security at farmers' households around the dam. At the same time, the farm is influenced by climate with a path coefficient of 0.288 and was also very significant. On the other hand, demographics had a negative effect on the path coefficient of -0.116 and the p-value of 0.054. The negative path coefficient indicated the opposite relationship, for example the greater the demographic variable the smaller was the food security. The greater demographic variable that is the older farmers', (which was represented by the husband's age), the greater the number of family members. This is the reason why the demographic variable had a negative path coefficient.

The strength of the indicator effect on each latent variable is indicated by factor loading, while the current condition is indicated by the average value of the measurement results (Table 6). Factor loading is obtained from SEM analysis, while the average value is obtained from the measurement of the existing conditions with a Likert scale, except the farmers' age and the number of family members using a ratio scale (according to Table 1). Almost all loading factors has a strong value, the majority > 0.9 and only a few indicators have a loading factor <0.9. This means that the strength of the indicators in each latent variable is very strong. The strength of this loading factor become a priority base in providing recommendations for improving food security. In addition, the existing condition in low score is also a priority consideration in improving food security.

Climate change significantly affects farm (Table 5). Based on the loading factor (Table 6), the effect of climate change on the declining farm production is stronger (0.986) than the effect on the declining farm income (0.967). Based on the production calculations, the average production falls by 20.9%. This decrease in production is higher than findings in India that climate change reduces agricultural productivity in the range of 7% -13% [4]; and decreased corn production ranges from −7% to −41% and on soybean ranges from −8% to −45% [42]. However, based on

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the average score of the farmers' answers, the effect on the declining farm income is greater (4.0) than the effect on the declining production (3.9). Nevertheless, the conclusion from the two indicators shows the strong influence of climate change on the decline in production and farm income.

Demographics influenced farming with a rather high error, namely 5.4% (Table 5). Although both loading factors of the indicators were equally strong (Table 6), this variable is not a priority in the recommendation for increasing food security. The demographic variables consist of the indicators of the farmers' age and the number of family members. The average age was 47 years; meanwhile the average of family member was four persons. This finding was explained in [43] that the older farmers involved in farming, causing the decreasing amount of agricultural production. This is due to the decline in the performance and productivity of the old farmers. The agricultural production also tends to decline if the number of households increased the production cost rather than increasing the output value. This finding supported [44] that the number of family members reduced the welfare of farmers, because the bigger the number of family members, the higher household expenses, then this condition would reduce the farmer's welfare.

Farming significantly influences food security (Table 5). The most powerful indicator is farming for household consumption, with a loading factor of 0.948 and a score of 3.9 (Table 6). This means that farmers who did their farm to meet household consumption had not reached a maximum score of 5. The second-order loading factor (0.905) is farm income for household consumption, with a slightly higher score of 4. The third sequence is growing consumption plants, with a loading factor of 0.891 and a score of 3.9. Even though the loading factor is also strong, farmers did not have to plant consumption crops such as rice, corn, and vegetables because the consumption can be obtained from the farm income. The consideration is that the choice of plant species must adjust to the suitability of the owned land. Other crops such as tobaccos are not directly consumed by the farmers families, but their income from selling tobacco also supports their food security.

Food security as a dependent latent variable has a number of indicators with strong loading factors (all above 0.8) and quite a variety of the existing condition scores. Food sufficiency is still dominated by carbohydrates, vegetables, and vegetable protein. Priority improvement is given based on the existing condition score which was still low. The priority of the increasing consumption sufficiency needs to be increased in milk consumption (score 3.3), fruits (score 3.4), and animal protein (score 3.9). If the price of milk is still far from the affordability of the farmers purchasing power, then the fulfillment of consumption of fruit and animal protein should still be met if the farm provides these needs. Therefore, farmers need to plant fruit and raise small-scale livestock and or fish farming for household consumption purposes.

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CONCLUSION

Most farmers' perceptions about climate change is the unpredictable weather, so it is hard to predict when the flooded dam happens or when it is dry. In the climate change situation, farm production has decreased by an average of 20.9%. Some rice farmers even failed to harvest, and they switched to tobaccos. Their adaptation efforts on climate change were changing the crops and starting earlier cultivation to avoid the dam flooded suddenly.

Their farm production and income were not enough for their food security. It needs support from the non-farming income. Climate change significantly affected farm production, in essence, farm production and non-farm income positively determined the food security. It was still dominated by carbohydrates, vegetables, and vegetable protein.

Recommendations are given to several parties. The government and universities need to provide assistance to farmers in order to adapt to climate change. Researchers need to develop research in terms of commodities and cultivation that are adaptive to climate change, as well as community empowerment strategies in adapting climate change.

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