Indonesian Journal of Sustainable Agriculture and Environmental Sciences (IJSAES) E-ISSN 3109-1377
Vol. 1 No. 3, 120-133, 2025

Assessing the Impact of Climate Change on Food Security: Empirical Evidence from Shrimp Farmers in East Java, Indonesia

Fatahullah[1♥], Syauqi Agung Firmanda[2], and Akbar[3]

[1]Department of Agribusiness, Faculty of Agriculture and Fisheries, Universitas Cordova, Taliwang, Indonesia
[2]Master of Agricultural Economics, Faculty of Agriculture, Universitas Brawijaya, Malang, Indonesia
[3]Department of Agribusiness, Faculty of Agriculture, Universitas Muhammadiyah Makassar, Makassar, Indonesia

♥Correspondence: fatahullahyasin98@gmail.com

Abstract
Background: Climate change poses a profound and escalating threat to global food systems, particularly for small-scale aquaculture communities such as shrimp farmers in coastal regions, whose livelihoods and food security are increasingly vulnerable to environmental variability and extreme weather events. **Methods:** This study investigated the impact of climate change adaptation strategies on household food security in Bangil Regency, East Java, Indonesia, based on a comprehensive analysis of 1500 shrimp farmers. Using the innovative Multivariant Probit (MVP) method to identify factors influencing the decision to adopt adaptation practices. These factors include changes in the timing of clear fry dispersion, acceleration of harvest time, polyculture practices, and changes in the type of clear fry. We also employed the Ordered Probit Model to evaluate the impact of climate change adaptation on food security, as measured by the food insecurity experience score. **Results:** A strong positive relationship was revealed between the level of adaptation applied and the resilience of household aquaculture among shrimp farmers. This correlation shows that the more intense adaptation is implemented, the better the food security status of households. **Conclusion:** This study shows that climate change adaptation has a positive impact on food security. These findings underscore the need for adaptation strategies, especially for small-scale farmers, and tailored interventions to ensure food security in the face of climate change challenges.

Keywords: adaptation; climate change; food insecurity; multivariant probit (MVP); probit

Introduction

Climate change is a complex global threat and it is very important to pay attention to (Sekiyama, 2022). The causes and consequences of climate change are diverse, and this is further highlighted by an interesting irony: low-income countries, which contribute the least to climate change, are the most affected (Dhakal & Pokhrel, 2022). The climate change impact events that occur will be very vulnerable to have a severe negative impact on the agriculture and fisheries sectors. Therefore, farmers and ranchers are forced to respond in the form of adaptation to climate change (Wong et al., 2022); Tang & Hailu, 2020). Adaptation to climate change is essential for the sustainability of shrimp farming and mitigating its negative impact on farmers' income and food insecurity. It is clear that, in recent years, climate change has become a major challenge for various industries and sectors, including agriculture and fisheries (Cholo et al., 2018). Climate change not only impacts production, but also increases the risk of food insecurity. Increased risk of floods, droughts, and extreme weather can disrupt local and national food supplies, lead to price instability, and increase vulnerability to hunger and malnutrition (Tresnati, et al., 2022).

The impact of climate change on pond farmers is increasingly real. According to the Food and Agriculture Organization of the United Nations (FAO), global shrimp production was only 71 tons in 1956 and gradually increased to about 2 million tons in 1970. Then it reached 6.22 million tons in 2019, most of which came from Asia. For example, the four largest countries in the world, China, Indonesia, Vietnam, and India produced about 4.4 million tons in 2019. If presented, the four countries have contributed more than 70% of global shrimp production (FAO, 2021). However, shrimp production has decreased due to climate change, not only felt by shrimp pond business actors, but also by fishery business actors (Z. Ahmed, 2023; Nadarajah, 2020; Oparinde, 2021). Climate change conditions confirm that pond business actors are one of the sectors that are considered at risk (Vecchio et al., 2024). This presents a new challenge to immediately adapt to climate change, as well as maintain the quality and stability of shrimp production, one of which is improving aquaculture infrastructure facilities (Nadarajah, 2020)). Realizing the economic potential of shrimp resources, the Indonesian government needs to pay serious attention to the threat of climate change (S. Ahmed & Fatema, 2023); (Galappaththi & Schlingmann, 2023).

Reviewing previous research, it was found that climate change adaptation strategies are categorized into three levels, namely mitigation options at the local level, multi-level adaptive strategies, and approaches at the community level. As for the shrimp farming sector, climate change adaptation is found in the form of mixed mangrove shrimp cultivation (Chary et al., 2024), known as a multi-tiered adaptive strategy. Meanwhile, preventive measures at the household level can be taken by increasing the depth of the pond, repairing the embankments around the pond, lining the shrimp pond using plastic sheets, and improving water quality by using settling ponds (Islam et al., 2023). Judge et al., (2020). found that shrimp farmers are generally incentivized to improve water quality in order to improve production efficiency. Based on these findings, it shows that the application of water quality management techniques is an effective coping mechanism. However, the implementation of this countermeasure strategy varies between regions, even between households in one region due to socioeconomic factors. It also depends on how farmers view the impacts of climate change.

Although there is a lot of literature that conducts research related to climate change adaptation. However, most of these studies only look at the impact of climate change on ecosystems (Perisha, B., et al., 2022), fisheries productivity (Illahi et al., 2023), and food security (M. S. Rahman et al., 2022), however, research on climate change adaptation to the food security of traditional shrimp farmers is still rare. Therefore, to fill the gap, the author is interested in conducting research by formulating goals; 1) identify factors that influence decision-making of shrimp farmers to carry out climate change adaptation practices, 2) assess the impact of climate change adaptation on the food security of shrimp farmers. This research can be used as a reference for the government in formulating strategies and policies to deal with climate change issues, such as handling cases of poverty and hunger of traditional shrimp pond business actors. This study will measure food insecurity using the Food Insecurity Experience Scale (FIES), which is a measuring tool to measure progress in achieving the Sustainable Development Goals (SDGs) related to ending hunger and ensuring food access. Through these measurement tools, this study contributes to the assessment of the prevalence of food insecurity in the population (both to monitor the SDGs and national use), to identify populations that are vulnerable to food insecurity, to guide and monitor the impact of food security policies and programs.

Methods

Determination of Research Location

We determine the location using the Multistage sampling method. First, three districts in East Java, namely Sidoarjo Regency, Bangil Regency, and Banyuwangi Regency were purposively chosen as research locations because they are the areas with the most pond workers in Indonesia (Central Statistics Agency, 2022). Furthermore, one district with the most shrimp farmers in East Java, namely Bangil Regency, will be selected. The determination of the location of the sub-district is determined deliberately and based on information from the Fisheries Service and the Central Statistics Agency, then respondents are selected at the sub-district level based on the largest number of shrimp farmers.

Determination of Respondents

The determination of respondents was determined using the simple random sampling method. First, a list of shrimp pond households in three selected sub-districts in Pasuruan Regency will be censused, allowing for the establishment of a research sampling framework. The next step will be selected using a formula; the results of the formula will then be sampled in an oversample, with 500 respondents per sub-district, so that a total of 1500 samples of shrimp farming households will be obtained.

Data Analysis

Factors influencing adaptation decisions

This study models climate change adaptation strategies with the premise that shrimp farmers have a choice between adopting or not adopting adaptation strategies. The study applied a randomized utility approach to estimate shrimp farmers' decisions in adopting adaptation strategies. Based on this approach, the amount of benefits that shrimp farmers get by following adaptation strategies is unknown (Osato Itohan Oriekhoe et al., 2024); Mitter et al., 2024). However, the benefits gained from the decision to adopt an adaptation strategy are higher than those who do not adopt any strategy. The derivative usefulness of the application of adaptation strategies can be modeled as a function of the observable factors in the latent variable specification (Equation 1).

$A_i^* = X_i \propto + ; = 1 \; u_i A_i^*$ if $A_i^* > 0$ and 0 otherwise (1)

Where A_i^* is a dummy variable that has a value of 1 if shrimp farmers adopt a climate change adaptation strategy and 0 if it is the opposite. $\propto$ is the vector of the variable to be estimated, and u_i is the margin of error. FurthermoreX_i, it is noted as a socio-economic characteristic factor that can influence farmers in making decisions to adapt.

Assessing the impact of adaptation strategies on climate change

We use the ordered probit model to assess the impact of adaptation strategies on the food security category of shrimp farmers. We categorize the dependent variables in this study with values of 1 (food security), 2 (enough food), and 3 (food insecurity). The ordered probit model is more suitable for use in this study than the multinominal model because of the dependent variable category of the ordinal wfp (2008). The ordered probit model is assessed using Equation 2.

$ϒ\_c.fc.S = \beta + e\_i\chi_i$ (2)

Where *'ϒ_c.fc.S* is the observed variable (a categorised food insecurity experience score) x is the explanatory variable (adaptation strategy), *e* is N(0.1), and I = 1, 2, 3… N. Furthermore, the probability of the ordered probit model can be written as Equation 3.

$$Prob\ [y_i = j] = \varphi\ (\mu_j - x_i\beta) - \varphi\ (\mu_j - 1 - x_i\beta) \quad (3)$$

Where the cumulative distribution function is given by φ, and j is the categorised food insecurity experience score.

Results and Discussion

Descriptive Statistics

In this study, we selected 1500 households as intervention targets based on the selection we described in the previous discussion. Table 1 shows the descriptive statistics of the variables used in this study. An average of 63% of farmers understand climate-related change. We also ask deeper questions and learn that shrimp farmers understand climate change based on traditional observations of seasonal changes and high rainfall intensity. Meanwhile, as many as 53.3% of shrimp farmers have implemented adaptation strategies. The average age of farmers in this study was 51 years, 8 years of education (or high school), 20 years of experience, and 3 family members. 28.7% of shrimp farmers have electricity in pond land, and as many as 33% have machine equipment as tools for shrimp pond business needs, while the average distance to the shrimp pond market is around 5,096 kilometers. The financial capital group of shrimp farmers is such as access to credit 54.3% and financial savings 74.8%. Shrimp farmers not only earn income from shrimp pond cultivation activities, but also from activities outside the pond, such as private labor, agriculture, trade, honorary, self-help and entrepreneurship, so that work outside shrimp ponds is 56.7%.

Furthermore, the social capital group showed that as many as 54.7% of shrimp farmers participated in farmer group activities, 35% in agricultural cooperatives, and 74.3% participated in social activities, such as mutual cooperation, cultural and religious. 47.3% of shrimp farmers receive weather information accessed through Radio/TV, smartphones, and fellow shrimp pond business actors. Finally, the farmers' area is 5,561 hectares with 23.1% of them having increased irrigation to supply pond water. The dependent variable in this study was food security which was measured based on the prevalence of eight questions on the Food Insecurity Experience Scale. Then we will assess the practices of climate change adaptation affecting food status. The score in FAO (2022) is if 1 assesses food security, 2 assesses food security, and 3 assesses food insecurity. The average value of the FIES variable was 2.093, indicating that the average farmer was in the category of sufficient food.

Determinants of Climate Change Adaptation Practices

The findings of correlation coefficients in various adaptation steps suggest that adopting one adaptation step can accelerate the adoption of other adaptation steps because they complement each other (Gebre et al., 2023a). From this statement, we draw the conclusion that the correlation between adaptations justifies the use of the MVP model (Table 3). The significant likelihood ratio (LR) test also showed that the use of the MVP model was justified (Table 4) (Gebre et al., 2023b). A significant Wild-chi-square value indicates a good model fit.

Determinants of Climate Change Adaptation Practices

The findings of correlation coefficients in various adaptation steps suggest that adopting one adaptation step can accelerate the adoption of other adaptation steps because they complement each other (Gebre et al., 2023a). From this statement, we draw the conclusion that

the correlation between adaptations justifies the use of the MVP model (Table 3). The significant likelihood ratio (LR) test also showed that the use of the MVP model was justified (Table 4) (Gebre et al., 2023b). A significant Wild-chi-square value indicates a good model fit.

Table 1. Descriptive statistics of the variables used in the study

Variables	Definition	Mean	Std. Dev
CC	Dummy 1 if the farmer feels CC; 0 if others	0.630	0.428
FIES	1 if food security; 2 if Enough Food; 3 if Lack of Food	2.093	0.569
Adapt	Dummy 1 if Adapting; 0 if not adapting	0.533	0.500
Human Capital			
Age	Farmer age in years	51.526	11.728
Edu	Highest education level in family (years)	8.3	3.868
Exper	Farmer experience in farming activity (year)	20.933	13.381
F-Numb	Total number of family numbers	3.4	1.146
Physical Capital			
Elect	Dummy 1 if farmers have agricultural electricity; 0 for others	0.287	0.528
Engine	Dummy 1 if farmers have agricultural machinery; 0 for others	0.330	0.478
Dmarket	Distance from agricultural land to agricultural market (Km)	5.096	2.873
Financial Capital			
Credit	Dummy 1 if farmers have access to credit; 0 for others	0.543	0.543
Saving	Dummy 1 if farmers have saving; 0 for others	0.748	0.554
Off-farm	Dummy 1 if farmers have a job other than the farm; 0 for others	0.567	0.498
Social Capital			
F-Group	Dummy 1 if farmers participated in a pond group; 0 for others	0.547	0.481
Cooper	Dummy 1 if farmers participate in an agricultural cooperative; 0 for others	0.350	0.538
S-Activity	Dummy 1 if farmer participated in social activity; 0 for others	0.743	0.521
Imarket	Dummy 1 if farmers have market information; 0 for others	0.450	0.635
W-Info	Dummy 1 if the farmers have weather information; 0 for others	1.473	0.509
Natural Capital			
t-area	Total area of land cultivated (Ha)	5.561	3.719
Warter_s	Dummy 1 if farmers have improved water supply; 0 for others	0.231	0.457

Source: Primary Data Processed

Table 2. Number of farmers who implement and do not implement adaptation strategies

Category	Amount (Person)	Percentage (%)
Adoption	800	53.33
Not Adopted	700	46.67
Total	**N=1500**	**100**

Source: Primary Data Processed

Table 3. Correlation Coefficient Between Adaptation Measures

Adaptation measures	changing the type of shrimp fry	Polyculture	Speed up the harvest period	Change in stocking time
Changing the type of shrimp fry	1	0.438** (0.062)	-0.130* (0.067)	0.052 (0.084)
Polyculture		1	-0.143** (0.066)	0.219** (0.084)
Speed up the harvest period			1	-0.140* (0.076)
Change in stocking time				1

Not: *,**,***, indicate significance at the 10%, 5%, and 1% levels, respectively. The values in parentheses are standard errors.

Source: Primary Data Processed

Table 4. Parameter estimation from probit models to estimate the determinants of adaptation practices

Variable	Coefficient	Std. Error	z	p> |z|
Human Capital				
Age	-0.039	0.016	-2.430	0.015**
Edu	0.108	0.051	2.100	0.036**
Exper	0.387	0.258	2.861	0.072*
F-Numb	23.248	0.564	3.146	0.510
Physical Capital				
Elect	-0.005	0.060	-0.090	0.927
Engine	0.063	0.055	1.150	0.250
Dmarket	-0.075	0.054	-1.400	0.162
Financial Capital				
Credit	0.785	0.350	2.240	0.025**
Saving	-0.369	2.922	-0.310	0.800
Off-farm	9.625	3.856	1.294	0.030**
Social Capital				
F-Group	0.814	0.338	2.410	0.016**
Cooper	0.351	0.437	0.800	0.422
S-Activity	11.511	5.458	1.380	0.018**
Market	-0.538	2.889	-0.551	0.641
W-Info	-2.620	0.670	-3.910	0.000***
Natural Capital				
t-area	2.821	0.648	1.461	0.010**
CCI	0.655	0.333	2.000	0.046**
_Cons	-0.781	1.388	-0.560	0.574
The number of obs			1500	
LR chi2(12)			212.151	
Prob. > chi2			0.000	
Pseudo R2			0.615	
Not: *,**,***, demote significance on 10%, 5%, and 1% respectively				

Source: Primary Data Processed

We used a multivariate probit (MVP) analysis to identify shrimp farmers' decision-making factors in implementing adaptation strategies (See Table 4). Human resources such as age and education have a significant effect on 5% each, and experience at a significant level of 10% with negative coefficient values. Physical capital (elect, machin, and Dmarket) has no significant effect on any level. Variables that have no effect do not contribute to shrimp farmers' decision-making to adapt. Financial capital (access to credit and ownership of jobs outside the pond) has a significant effect on each 5%. Social capital has a positive and significant effect on the level of 5% (farmer groups), social activities (5%), and irrigation information (1%). Finally, natural capital such as area information and climate change has a positive and significant influence on 5% each.

The significant correlation coefficients of the steps can indicate that the various choices of adaptation measures are interrelated (Table 4). A positive sign of the correlation coefficient implies that the application of one approach will increase the likelihood of implementing one or more other actions. Meanwhile, a negative sign indicates that the two actions have an inversely proportional relationship (Obsi Gemeda et al., 2023; Gebre et al., 2023a; Gebre et al., 2023b). Shrimp farmers who change their adaptation strategies, changing the type of shrimp fry, for example, will tend to adopt polyculture and are less likely to accelerate the harvest period, as well as changes in stocking time. Similarly, shrimp farming households that use changes in the type of shrimp fry as an adaptation measure tend not to accelerate the harvest period. Negative and positive values in the MVP estimation coefficient (table 4) show the high or low influence of variables on farmers' decision-making in adapting (M. S. Rahman et al., 2023). For example, a negative coefficient on an empirical variable indicates that shrimp farmers tend to adopt Changing the type of shrimp fry as an adaptation step is lower when compared to farmers who have a higher level of education or with an older age. Similarly, positive coefficients in the variables of age and education had a higher probability of adopting Polyculture as an adaptation measure when compared to other variables that had negative coefficients (e.g., variables of experience and job ownership other than ponds).

Assessing the impact of adaptation strategies on climate change

In this section, we present the results of a probit model to assess the impact of climate change adaptation strategies on food status (Table 6). The results of the probit estimate show that farmers who adapt to changes in the type of shrimp fry have a lower probability of 0.20% to be included in the category of almost food insecure. In the categories of food security and food sufficiency, the probability increased by 0.47% and 0.10%, respectively. Meanwhile, the adaptation strategy with the polyculture method had a significant effect and increased the probability by 0.50% and 1.47%, respectively, in the food security and sufficient food categories. The category of food deficiency was successfully lowered by 0.31%. Furthermore, the adoption of the practice of changing stocking time had a significant effect and increased the probability by 0.47% and 0.70% respectively in the food security and sufficient food category, and succeeded in reducing the probability by 1.17% in the food shortage category. Furthermore, the adoption of the accelerated harvest period had a significant effect and succeeded in increasing the probability of 0.67% and 0.31%, respectively, in the categories of food security and food sufficiency. Meanwhile, in the category of food shortages, the probability is successfully lowered by 0.60% if this method is practiced as an adaptation strategy.

The results of the probit estimate (table 6) show that the longer shrimp farmers carry out this adaptation strategy, the more likely they are to reduce their food insecurity. Meanwhile, in the category of food security and food security, it shows that the longer shrimp farmers carry out this strategy, the more it will increase the resilience of shrimp farmers. This is reinforced by research Le & Armstrong, 2023 and Rahman et al., 2024, revealed that by changing the type of climate-resistant fry, it will reduce the risk of disease attacks on shrimp. Initially, shrimp farmers at the research site used tiger shrimp fry types, but due to climate change they switched to vannamei shrimp fry. Vannamei shrimp is considered fry resistant to weather and climate, resistant to pest and disease attacks, and slightly sluggish with a risk of depression (Shi et al., 2024).

Meanwhile, the adaptation strategy with the polyculture method found that adoption had a significant effect and increased the probability in the categories of food security and food sufficiency. Meanwhile, in the category of food shortage, it succeeded in reducing the probability, which means that the application of polyculture is able to reduce the food insecurity status of shrimp farmers. Polyculture adoption is the most common and dominant adaptation adopted by shrimp farmers in the study site. This is the most efficient and effective strategy to increase their revenue and increase their production. That way, the profits they get will also increase and access to food will also be easier for them. According to key informants, the polyculture adoption method is the most popular method in Bangladesh (Jamal, 2024) Kemduian is applied in the community. The adoption of shrimp and milkfish mixture cultivation applied at the research site is considered a method of shrimp and milkfish mixture cultivation that is able to reduce the risk of failure and losses due to climate change (M. A. Islam et al., 2019). However, the problem at the research site is that they do not receive technical support as a follow-up to the information they get from non-governmental organizations. This is because there are still not massive agricultural and fisheries extension activities at the research site.

Table 5. Assessment of the impact of climate change adaptation strategies on food security

Shape Adaptation	Marginal effects							
	Coef.	Z-Value	Food Security (%)		Enough Food (%)		Food Insecurity (%)	
			dy/dx	dy/dx	dy/dx	dy/dx	DY/DX	Z-value
changing the type of shrimp fry	-0.015	1.710*	0.001	2.560**	0.047	3.110***	-0.002	-1.710*
Polyculture	0.029	4.120***	-0.005	3.740***	0.147	2.590**	-0.031	-2.830***
Speed up the harvest period	0.719	3.900***	0.047	2.870***	0.070	2.580***	-0.117	-3.480***
Change in stocking time	0.905	4.310***	0.067	2.200**	0.031	2.320**	-0.060	-2.560**
Log-likelihood	-156.803							
LR chi2(17)	196.960							
Prob>chi2	0.000							
Pseudo R2	0.386							
Not: *,**,***, demote significance on 10%, 5%, and 1% respectively								

Source: Primary Data Processed

Furthermore, the adoption implemented by shrimp farmers at the research site can indicate that the strategy implemented is effective in responding to the occurrence of long droughts and high rainfall intensity. The practice of changing stocking time is carried out because climate change that occurs is difficult to avoid suddenly due to the use of traditional patterns and the lack of adoption of modern technology among farming communities (Kabir et al., 2024). Adoption is traditionally predicted by shrimp farmers at the research site through natural signs such as wind direction, air humidity, animal behaviour, and environmental changes. According to key informants, the observation is quite effective as information on weather changes from the rainy season to the dry season or vice versa. In addition, changes at the time of fry stocking, it is predicted based on the weather, that is, if for one month the weather shows summer, then farmers will prepare shrimp fry stocking activities in ponds. Although this method is less effective, this step can at least minimize large losses. Meanwhile, the adoption of harvest acceleration is carried out as a step to respond to climate change. The adoption is an action to accelerate the spread of shrimp fry and the harvest period to catch up with prices due to frequent price fluctuations. The adoption method is a new step taken by those who work as shrimp pond cultivators. So this method is new enough to practice and efficient enough to reduce the price loss of shrimp production. Fluctuations or uncertainty in shrimp prices are quite risky because it will have an impact on their net income (Beras et al., 2024). The adoption of changes in harvest time at the research site was carried out when the shrimp were 2 months old, where the selling price was still quite good. Although the act of accelerating the harvest time to get the right price can be said to impose will. However, this action can be considered the only option available to farmers to cope with conditions that are difficult to predict accurately.

Shrimp farmers are identified as the majority of food security and are indicated to have access to adequate food, but there are still vulnerabilities to food shortages that need to be addressed (See Table 7). The proportion of food insecurity status shows that shrimp farmers are almost food insecure due to limited access to food, and are still indicated to be more vulnerable to food insecurity. Factors that affect the status of food security are caused by the large number of family dependents owned by households (Niles et al., 2021) , the age of the respondents who are no longer productive (Umaroh, 2020); Rodríguez, C., et al., 2022; Triastuti, 2022), respondents' education is still low (Umaroh, 2020); Rodríguez, C., et al., 2022; Triastuti, 2022), there is no diversification of livelihoods or income still depends on shrimp farming business (Biswas & Mallick, 2021); Yusriadi & Cahaya , 2022; Adhiana et al., 2022; Saad et al., 2023; (Jayanti, E. W., et al., 2023)A lack of experience in the cultivation of shrimp is lacking. (Ukonu et al., 2024); (Olawuyi & Ijila, 2023), activities in pond groups (Niles et al., 2021), still lack of access to weather information (Rusmawati et al., 2023); Olawuyi, 2019), limitations in managing pond land due to ownership status (Pakravan, C, 2022); Pakravan, C., et al., 2022), and the small land area that affects the amount of income received (Olarinde et al., 2020; Ukonu et al., 2024; Ojo et al., 2023; Olawuyi & Ijila, 2023).

There is still a status of food insecurity experienced by shrimp farmers at the research site, which can be summarized that the research site still needs serious attention. Such as special efforts to increase food security in farmer groups that are identified as almost food insecure. These efforts can be done in various ways, such as increasing access to food resources, such as through social assistance programs or the development of small and medium enterprises (SMEs), increasing the knowledge and skills of shrimp farmers in managing food resources. improve infrastructure and access to markets. Increasing the diversification of shrimp farmers' sources of income, and emphasizing the need for farmers to take part in social institutions. In addition, there is a need for intervention from the government through holistic strategic policies that involve the poor in aquaculture development as part of national development, so that shrimp farmers can be sure to get benefits. Therefore, institutional and infrastructure assistance is urgently needed to diversify production and trade with poor households as the main target of interventions to address the climate change crisis.

Conclusion

This study aims to analyze the factors that affect shrimp farmers in practicing adaptation strategies in response to climate change that occurs, and secondly to analyze the influence of climate change adaptation strategies on the food security of shrimp farmers. Finally, evaluating the impact of climate change adaptation strategies on the food security of shrimp farmers. Based on the results of the study, we found that most shrimp farmers have become aware of climate change and are practicing adaptation strategies in response to the threat of climate change through the act of changing the type of shrimp fry, adopting polyculture methods in their ponds, accelerating the harvest period from the original 3 months to 2 months as a measure to minimize losses in shrimp prices that often fluctuate. Adjust the timing of sowing shrimp seeds. We found that the adaptation practices of shrimp farmers in responding to climate change risks show positive results in increasing their food security and can reduce food insecurity status, where shrimp farmers who practice adaptation tend to have a better food security status and lower levels of food insecurity than those who do not adapt. In addition, we also found that in human capital groups such as age, education level, and experience, in financial capital groups such as access to credit and employment outside shrimp farming, social capital groups, such as farmer groups, social activities, and irrigation information, natural capital groups, such as pond land area and climate change information have an important role in shrimp farmers' decision-making in implementing adaptation strategies.

Finally, we gave some advice. First, the government and related institutions need to increase shrimp farmers' access to more accurate weather information and more up-to-date adaptation technology in accordance with technological developments through the role of more authoritative counseling and training. Second, shrimp farmers are encouraged to diversify their sources of income by developing businesses outside of shrimp farming to reduce their dependence on shrimp farming alone. Third, increasing participation in the social activities of farmer groups to strengthen their social capital, which has been proven to have an important role in adaptation decision-making. Fourth, providing policy and infrastructure support provided by the government to support climate change adaptation practices, such as better irrigation development and easier market access. Finally, researchers who are interested in learning more about the impact of adaptation strategies on food security in the fisheries sector are expected to further expand the scope of the sample with a more comprehensive methodological approach to obtain more representative and in-depth results on climate change adaptation strategies and food security of shrimp farmers.

Acknowledgements

The author would like to express gratitude to the research team for their collaboration and contributions throughout the implementation of this study. Sincere appreciation is also extended to the respondents who willingly provided information, enabling the necessary data for this research to be obtained adequately and in accordance with the research objectives.

References

Adhiana, A., Ariani, R., Riani, R., Eriani, M., & Basyar, M. J. (2022). Analysis of Income and Expenditure Based on Fishermen's Households The Level of Food Security in the Term District of Bireun Regency. *Agribusiness Media*, *6*(2), 250–261. https://doi.org/10.35326/agribisnis.v6i2.2806

Ahmed, S., & Fatema, N. (2023). Factors and practices: farmers' adaptation to climate change in Bangladesh. *Journal of Water and Climate Change*, *14*(1), 123–141. https://doi.org/10.2166/wcc.2022.216

Ahmed, Z., & Ambinakudige, S. (2023). Does land use change, waterlogging, and salinity impact on sustainability of agriculture and food security? Evidence from southwestern coastal region of Bangladesh. *Environmental Monitoring and Assessment*, *195*(1), 74. https://doi.org/10.1007/s10661-022-10673-w

Biswas, B., & Mallick, B. (2021). Livelihood diversification as key to long-term non-migration: evidence from coastal Bangladesh. *Environment, Development and Sustainability*, *23*(6), 8924–8948. https://doi.org/10.1007/s10668-020-01005-4

Chary, K., van Riel, A., Muscat, A., Wilfart, A., Harchaoui, S., Verdegem, M., Filgueira, R., Troell, M., Henriksson, P. J. G., de Boer, I. J. M., & Wiegertjes, G. F. (2024). Transforming sustainable aquaculture by applying circularity principles. *Reviews in Aquaculture*, *16*(2), 656–673. https://doi.org/10.1111/raq.12860

Cholo, T., Fleskens, L., Sietz, D., & Peerlings, J. (2018). Is Land Fragmentation Facilitating or Obstructing Adoption of Climate Adaptation Measures in Ethiopia?

Sustainability, *10*(7), 2120. https://doi.org/10.3390/su10072120

Dhakal, S., & Pokhrel, H. (2022). A Review on Evaluation of Changes in Blood Parameters in Dairy Buffaloes Affected with Clinical and Sub-Clinical Mastitis. *Malaysian Animal Husbandry Journal*, *2*(2), 40–42. https://doi.org/10.26480/mahj.02.2022.40.42

Galappaththi, E. K., & Schlingmann, A. (2023). The sustainability assessment of Indigenous and local knowledge-based climate adaptation responses in agricultural and aquatic food systems. *Current Opinion in Environmental Sustainability*, *62*, 101276. https://doi.org/10.1016/j.cosust.2023.101276

Gebre, G. G., Amekawa, Y., Fikadu, A. A., & Rahut, D. B. (2023a). Do climate change adaptation strategies improve farmers' food security in Tanzania? *Food Security*, *15*(3), 629–647. https://doi.org/10.1007/s12571-023-01348-6

Gebre, G. G., Amekawa, Y., Fikadu, A. A., & Rahut, D. B. (2023b). Farmers′ use of climate change adaptation strategies and their impacts on food security in Kenya. *Climate Risk Management*, *40*, 100495. https://doi.org/10.1016/j.crm.2023.100495

Judge, V., Nielsen, R., Asmild, M., & Nielsen, M. (2020). Do Aquaculture Farmers Have an Incentive to Maintain Good Water Quality? The Case of Small-Scale Shrimp Farming in Indonesia. *Ecological Economics*, *176*, 106717. https://doi.org/10.1016/j.ecolecon.2020.106717

Illahi, R. W., Syahputra, A. F., Aida, G. R., & Prajasti, C. N. (2023). The Effect of Climate Change on Capture Fisheries Production in the East Java Sea of Indonesia. *Journal of Agrimanex: Agribusiness, Rural Management, and Development Extension*, *3*(2). https://doi.org/10.35706/agrimanex.v3i2.8684

Ir Hj Joeharnani Tresnati, D. E. A., Yasir, I., & Ir H Ambo Tuwo, D. E. A. (2022). *Seaweed for Food Security, Environmental Mitigation, Welfare and Sustainable Development*.

Islam, M. A., Akber, M. A., Ahmed, M., Rahman, M. M., & Rahman, M. R. (2019). Climate change adaptations of shrimp farmers: a case study from southwest coastal Bangladesh. *Climate and Development*, *11*(6), 459–468. https://doi.org/10.1080/17565529.2018.1442807

Islam, R., Ahmed, R., Dey, B., Haque, M. S., Aktar, S., Bhuiyan, M. S., Arif, M. S., Habib Ador, M. A., Ul Haque, M. M., & Saha, N. (2023). Salinity hazard drives the alteration of occupation, land use and ecosystem service in the coastal areas: Evidence from the south-western coastal region of Bangladesh. *Heliyon*, *9*(8), e18512. https://doi.org/10.1016/j.heliyon.2023.e18512

Jamal, M. R. (2024). Blue grabbing of the green crop fields: A development conundrum in southwest coastal Bangladesh. *Land Use Policy*, *141*, 107161. https://doi.org/10.1016/j.landusepol.2024.107161

Jayanti Eka Wardani, N. A. S., Jamaluddin, A., & Zainal Badari, S. A. (2023). The Understanding of Household Food Security among Glutinous Rice Smallholder Farmer in Langkawi, Malaysia. *International Journal of Academic Research in Business and Social Sciences*, *13*(16). https://doi.org/10.6007/IJARBSS/v13-i16/18761

Kabir, K. H., Schneider, U. A., & Leggette, H. R. (2024). Three faces of climate change: Using Q-methodology to understand farmers' perspectives of climate change and adaptive capacity in Bangladesh's wetland areas. *Climate Services*, *34*, 100497. https://doi.org/10.1016/j.cliser.2024.100497

Le, N. T. T., & Armstrong, C. W. (2023). Choice of climate risk adaptive measures in shrimp farming—A case study from the Mekong, Vietnam. *Aquaculture Economics & Management*, 1–29. https://doi.org/10.1080/13657305.2023.2273483

Mitter, H., Obermeier, K., & Schmid, E. (2024). Exploring smallholder farmers' climate change adaptation intentions in Tiruchirappalli District, South India. *Agriculture and Human Values*. https://doi.org/10.1007/s10460-023-10528-1

Nadarajah, S., & Eide, A. (2020). Are Asian fresh and brackish water aquaculture production vulnerable or resilient towards climate change impacts? *Aquaculture Economics & Management*, *24*(3), 232–254. https://doi.org/10.1080/13657305.2019.1677802

Niles, M. T., Rudnick, J., Lubell, M., & Cramer, L. (2021). Household and Community Social Capital Links to Smallholder Food Security. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.583353

No Title. (n.d.). https://doi.org/Perisha, B., Widyartini, D. S., Piranti, A. S., Susanto, A. B., & Anggiani, M. (2022). The role of macroalgae for ecosystems and their response to climate change. Ocean, 47(1), 29-38.

Obsi Gemeda, D., Korecha, D., & Garedew, W. (2023). Determinants of climate change adaptation strategies and existing barriers in Southwestern parts of Ethiopia. *Climate Services*, *30*, 100376. https://doi.org/10.1016/j.cliser.2023.100376

Ojo, O. O., Amos, T. T., Balogun, O. L., & Oluwatayo, I. B. (2023). Economic Analysis of the Effect of Social Capital on Food Security Status of Micro-Credit Households in Ekiti State, Nigeria. *Global Journal of Economics and Business*, *13*(2), 165–175. https://doi.org/10.31559/gjeb2023.13.2.5

Olarinde, L. O., Abass, A. B., Abdoulaye, T., Adepoju, A. A., Adio, M. O., Fanifosi, E. G., & Wasiu, A. (2020). The Influence of Social Networking on Food Security Status of Cassava Farming Households in Nigeria. *Sustainability*, *12*(13), 5420. https://doi.org/10.3390/su12135420

Olawuyi, S. O. (2019). Building resilience against food insecurity through social networks. *International Journal of Social Economics*, *46*(7), 874–886. https://doi.org/10.1108/IJSE-11-2018-0624

Olawuyi, S. O., & Ijila, O. J. (2023). Correlates of farmers' resilience to food insecurity in South-West Nigeria. *International Journal of Research in Business and Social Science (2147– 4478)*, *12*(2), 330–341. https://doi.org/10.20525/ijrbs.v12i2.2376

Oparinde, L. O. (2021). Fish farmers' welfare and climate change adaptation strategies in southwest, Nigeria: Application of multinomial endogenous switching regression model. *Aquaculture Economics & Management*, *25*(4), 450–471. https://doi.org/10.1080/13657305.2021.1893863

Osato Itohan Oriekhoe, Olawale Adisa, & Bamidele Segun Ilugbusi. (2024). CLIMATE CHANGE AND FOOD SUPPLY CHAIN ECONOMICS: A COMPREHENSIVE ANALYSIS OF IMPACTS, ADAPTATIONS, AND SUSTAINABILITY. *International Journal of Applied Research in Social Sciences*, *6*(3), 267–278. https://doi.org/10.51594/ijarss.v6i3.885

Pakravan-Charvadeh, M. R., & Flora, C. (2022). Sustainable food consumption pattern with emphasis on socioeconomic factors to reduce food waste. *International Journal of Environmental Science and Technology*, *19*(10), 9929–9944. https://doi.org/10.1007/s13762-022-04186-9

Pakravan-Charvadeh, M. R., Vatanparast, H., Frongillo, E. A., Khakpour, M., & Flora, C. (2022). The assessment of an extended set of socio-economic determinants to explain anxiety and uncertainty, insufficient quality and food intake of Afghan refugees. *Public Health Nutrition*, *25*(3), 554–564. https://doi.org/10.1017/S1368980021004043

Rahman, M. M., Chowdhury, M. M. I., Al Amran, M. I. U., Malik, K., Abubakar, I. R., Aina, Y.

A., Hasan, M. A., Rahman, M. S., & Rahman, S. M. (2024). Impacts of climate change on food system security and sustainability in Bangladesh. *Journal of Water and Climate Change*, *15*(5), 2162–2187. https://doi.org/10.2166/wcc.2024.631

Rahman, M. S., Huang, W.-C., Toiba, H., & Efani, A. (2022). Does adaptation to climate change promote household food security? Insights from Indonesian fishermen. *International Journal of Sustainable Development & World Ecology*, *29*(7), 611–624. https://doi.org/10.1080/13504509.2022.2063433

Rahman, M. S., Zulfiqar, F., Ullah, H., Himanshu, S. K., & Datta, A. (2023). Farmers' perceptions, determinants of adoption, and impact on food security: case of climate change adaptation measures in coastal Bangladesh. *Climate Policy*, *23*(10), 1257–1270. https://doi.org/10.1080/14693062.2023.2212638

Rice, E., Bennett, A., Smith, M., Liverpool-Tasie, L. S., Katengeza, S., Infante, D., & Tschirley, D. (2024). Price volatility in fish food systems: spatial arbitrage as an adaptive strategy for small-scale fish traders. *Ecology and Society*, *29*(2), art13. https://doi.org/10.5751/ES-15076-290213

Rodríguez-Cruz, L. A., Álvarez-Berríos, N., & Niles, M. T. (2022). Social-ecological interactions in a disaster context: Puerto Rican farmer households' food security after Hurricane Maria. *Environmental Research Letters*, *17*(4), 044057. https://doi.org/10.1088/1748-9326/ac6004

Rusmawati, E., Hartono, D., & Aritenang, A. F. (2023). Food security in Indonesia: the role of social capital. *Development Studies Research*, *10*(1). https://doi.org/10.1080/21665095.2023.2169732

Saad, A. Z., Radi, T., Saida, S., & Al-Najjar, K. (2023). Estimating Some Indicators of Food Security for Rural Households. *Asian Journal of Agriculture and Food Sciences*, *11*(2). https://doi.org/10.24203/ajafs.v11i2.7171

Sekiyama, T. (2022). Climate Security and Its Implications for East Asia. *Climate*, *10*(7), 104. https://doi.org/10.3390/cli10070104

Shi, M., Jiang, S., Shi, J., Yang, Q., Huang, J., Li, Y., Yang, L., & Zhou, F. (2024). Evaluation of Genetic Parameters and Comparison of Stress Tolerance Traits in Different Strains of Litopenaeus vannamei. *Animals*, *14*(4), 600. https://doi.org/10.3390/ani14040600

Tang, K., & Hailu, A. (2020). Smallholder farms' adaptation to the impacts of climate change: Evidence from China's Loes As Plateau. *Land Use Policy*, *91*, 104353. https://doi.org/10.1016/j.landusepol.2019.104353

Triastuti, U. H. (2022). Mainstreaming Climate Change Mitigation Program Plans with Institutional Approaches at the Ministry of Transportation. *Journal of Transportation Research*, *34*(1), 9–22. https://doi.org/10.25104/warlit.v34i1.2094

O'Neill, I. C., Wallace, C. A., & Lowe, N. M. (2024). Household food security and dietary diversity in south-eastern Nigeria. *Maternal & Child Nutrition*, *20*(3). https://doi.org/10.1111/mcn.13599

Umaroh, R., & Pangaribowo, E. H. (2020). Determinants of rural household food security in Indonesia: the case of protein-based food consumption. *IOP Conference Series: Earth and Environmental Science*, *451*(1), 012038. https://doi.org/10.1088/1755-1315/451/1/012038

Vecchio, Y., Masi, M., Del Giudice, T., De Rosa, M., & Adinolfi, F. (2024). Technological innovation in fisheries and aquaculture: What are the "discourses" of the Italian policy network? *Marine Policy*, *159*, 105947. https://doi.org/10.1016/j.marpol.2023.105947

Wong, T. E., Ledna, C., Rennels, L., Sheets, H., Errickson, F. C., Diaz, D., & Anthoff, D. (2022). Sea Level and Socioeconomic Uncertainty Drives High-End Coastal Adaptation Costs. *Earth's Future*, *10*(12). https://doi.org/10.1029/2022EF003061

Yusriadi, Y., & Cahaya, A. (2022). Food security systems in rural communities: A qualitative study. *Frontiers in Sustainable Food Systems*, *6*. https://doi.org/10.3389/fsufs.2022.987853