Determining factors and barriers to the uptake of climate change adaptation strategies of agriculture and aquaculture farm households in Myanmar

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Abstract

Purpose – Climate change is an undeniable reality that threatens people's livelihoods. Flooding and saltwater intrusion, along with the rising sea levels, are affecting agricultural and aquaculture livelihoods in Myanmar's coastal areas. Although climate change adaptation is gaining popularity as a resilience strategy to cope with the negative effects of climate change, both agriculture- and aquaculture-farmers are more often deterred from implementing climate change adaptation strategies due to practical availability and socioeconomic barriers to adaptation. This study aims to evaluate the barriers and factors that influence farm household' choice of climate change adaptation measures.

Design/methodology/approach – This study was conducted with 599 farm households (484 rice-farmers and 115 fish farmers) based in the coastal areas of Myanmar during 2021–2022 to explore the farmer's choice of climate change adaptation measures and the determining factors. The multinomial logit regression (MLR) model was used to examine the factors influencing the farmers' choice of climate change adaptation strategies.

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Findings – The study found out that farm households use a variety of adaptation methods at the farm level, with building embankment strategy (23.4%) in agriculture and net-fencing measure (33.9%) in fish farming being the most popular adaptation strategies. Farmers' decisions to adopt climate change adaptation strategies are influenced by factors such as distance to market, education level of the household head, remittance income and the availability of early warning information, among others. The study also discovered that COVID-19 has had an impact on the employment opportunities of household members and the income from farming as well had a consequential effect on the adoption of climate change adaptation measures. Furthermore, lack of credit (42.4%), labor shortage (52.8%), pest and disease infestation (58.9%), high input costs (81%) and lower agricultural product prices (73%) were identified as major barriers to the adoption of climate change adaptation measures by both agriculture and aquaculture farm households.

Originality/value – This study demonstrates that the COVID-19 pandemic and farm-level barriers are the major factors influencing farm households' choice of climate change adaptation measures, and that removing practical farm-level barriers and encouraging the adoption of adaptation techniques as potential COVID-19 recovery actions are required. This study also highlighted that the adaptive capacity of agriculture and aquaculture farm households should be strengthened through formal and informal training programs, awareness raising, the exchange of early warning information and the development of proper credit scheme programs.

Keywords Climate change, Adoption, Adaptation strategies, Agriculture and aquaculture, Indigenous strategies

Paper type Research paper

1. Introduction and background

Climate change is now becoming an incontrovertible phenomenon that threatens livelihoods. Many scientists have confirmed that the impacts of climate change are larger in developing countries, as the countries rely on agricultural-based economies, which highly depend on weather conditions and natural resources [Intergovernmental Panel on Climate Change (IPCC), 2022]. Climate change is projected to threaten livelihood activities, agricultural productivity, incomes of farm households and food and nutrition security (FAO, 2019; IFAD, 2020). Global warming causes unavoidable increases in multiple climate hazards and present risks to humans and ecosystems. Communities in the coastline areas are increasingly affected by floods and saltwater intrusion along with the rise of sea levels (Eckstein *et al.*, 2021; IPCC, 2022). Continued sea level rise will exacerbate the impacts on coastal settlements and infrastructure, livelihoods and ecosystems. It is expected that if the global mean sea level rises by 0.15 m compared to 2020 levels, the population exposed to a 100-year coastal flood is projected to increase by 20% and it would be double at a 0.75 m mean sea level rise and triple at 1.4 m without population change and additional adaptation (IPCC, 2022).

Adaptation plays a key role in reducing exposure and vulnerability to climate change. It also determines the level of risk being exposed, the vulnerability of a system or community and socioeconomic development (Deressa *et al.*, 2009; Tun Oo, 2018; IPCC, 2022). There are increasing assessments on the adaptation actions to understand and estimate the magnitude and rate of climate change and associated risks (Tun Oo *et al.*, 2017; Sahoo and Moharaj, 2022; Nguyen and Bleys, 2023; Gemeda *et al.*, 2023). Despite the progress achieved, however, adaptation gaps are still present between current levels of adaptation and levels needed to respond to reduce the climate risks. The largest adaptation gaps exist in lower-income population groups and it is important to overcome such gaps by recognizing the constraints and barriers that limit adaptation (Tun Oo, 2018; IFAD, 2020; IPCC, 2022). Therefore, understanding the factors that influence the adaptation measures taken by farm households is crucial and important.

In a study conducted in Vietnam by Le *et al.* (2020), age, education level and income were identified as significant determinants of climate change adaptation measures. A study by

Gebre *et al.* (2023) found that younger farmers were more likely to adopt climate change adaptation measures than older farmers. Also, farmers with higher education levels and income were more likely to adopt adaptation measures than those with lower levels of education and income. Similarly, Hein *et al.* (2019) observed that income and education levels were key drivers of climate change adaptation strategies in Myanmar, with farmers with higher income and education levels being more likely to take adaptation methods than those with lower income and education.

Another study conducted by Vo *et al.* (2021) in Vietnam found that access to credit and agricultural extension services were significant factors in the adoption of climate change adaptation measures. Farmers who had access to credit and extension services were more likely to adopt adaptation measures than those who did not. Furthermore, a study conducted by Swe *et al.* (2015) in Myanmar, proved that access to information and social capital were significant factors in the adoption of climate change adaptation measures.

According to the recent Global Climate Risk Index report, Myanmar ranked 2nd on the list of climate change vulnerable countries (Eckstein *et al.*, 2021). The country generates most of the economic output from agriculture and related sectors, where these sectors heavily rely on the different hydroclimatic conditions. Recent studies stated that Myanmar is experiencing the worsening impacts of climate change, rising temperature and erratic rainfall. As a consequence the farm households were severely affected by these climate change extremes. The Myanmar Government has launched several initiatives to increase farm-level adoption of appropriate climate change adaptation measures in the agriculture sector [Department of Agriculture (DOA), 2019; Tun Oo, 2018; Tun Oo *et al.*, 2023]. Therefore, this study was designed to inform the policymakers and stakeholders who can use the information to design effective policies and programs that promote the adoption of adaptation measures by farm households in Myanmar.

Several authors pointed out that in the climate change, context exposure is triggered by both climatic factors (rainfall, extreme temperature, drought, etc.) and nonclimatic conditions (income, lack of agricultural equipment, etc.) and it is imperative to understand the combination of these stressors (factors) that exacerbate the vulnerability of farming households to climate change (Antwi *et al.*, 2017). The impacts of global pandemic COVID-19 affected many sectors of the economy and the significant impacts were on food and nutrition security, farm incomes, access to farm inputs and investment, as well as employment opportunities of the households in Myanmar [Lambrecht *et al.*, 2021; International Food Policy Research Institute (IFPRI) and Michigan State University (MSU)' Researchers, 2020]. There are perceived climate and nonclimatic stressors of climate vulnerability that limit the choice of climate change adaptation measures (Tun Oo *et al.*, 2017; Abbasi and Nawaz, 2020). Therefore, this study also looks at the barriers or constraints that limit the uptake of climate change adaptation strategies at the farm level in Myanmar.

A better understanding of climate change adaptation strategies of different farm households and their adoption of adaptation strategies is becoming a great concern for policymakers and development planners. Adaptation consists of two stages:

(1) perceiving the change in climate and deciding whether to take action; and

(2) deciding which climate adaptation measures to choose (Maddison, 2007; Deressa *et al.*, 2009; Tun Oo *et al.*, 2017).

In this context, this study also considers the perception of the impacts of climate change by farm households and the uptake of climate change adaptation measures at the farm level to reduce the negative impacts of climate change and natural hazards in the coastline areas of

Myanmar. The acceptance of climate change adaptation strategies is determined by the numerous demographic, socioeconomic and institutional characteristics (Deressa *et al.*, 2009; Obayelu *et al.*, 2014; Tun Oo *et al.*, 2017). This study estimates the factors determining the choice of climate change adaptation measures by farm households. In Section 2, we present research methodology, followed by our research findings and discussions in Section 3, and our conclusions and recommendations to improve the uptake of climate change adaptation measures of farm households in Myanmar are presented in Section 4.

2. Research methodology

2.1 Study areas and data

With the abovementioned statements and hypotheses, this study was conducted in Myanmar Yangon and Ayeyarwaddy coastal areas. The Pyapon district in the Ayeyarwaddy region comprises four Townships (Bogale, Pyapon, Kyaiklat and Dedaye), which include 298 village-tracts and 1,450 villages. Flooding and saltwater intrusion to farmlands were frequently recorded in Kyaiklat and Dedaye Townships. Kyaiklat Township includes 87 village tracts and 18.7% of households are headed by women. Dedaye township includes 40 village tracts, with around 23.1% of the households headed by women. Kyauktan Township is located in the South-East area of the Yangon region and consists of 32 village tracts with 20.2% of the households being women-headed [Ministry of Immigration and Population (MIP), 2017; Tun Oo, 2018]. This study covers the two coastal areas most afflicted by saltwater overflow and floods in Myanmar, where the Dedaye, Kyaiklat and Kyauktan Township were reported as the areas most affected by the climate-related extremes (Tun Oo *et al.*, 2017; MIP, 2017). This empirical research study was carried out in 12 communities, of which six *in Dedaye and Kyaiklatt Township* and six in Kyauktan Township (Figure 1). By selecting 12 communities in these three townships, the impacts of saltwater intrusion and flooding at the individual farm level could be better understood.

Gender and ethnic-related questions were developed for the village profile sampling areas and women and minority participation in the research assessment were taken into consideration. The questionnaires were prepared and selected based on literature research and after discussion with key experts and local stakeholders. A total of 50 respondents from each sampling community were invited for interviews and, out of 12 sampling communities,

Figure 1.
Map showing the study areas, Kyaiklat and Dadeye Township in Ayeyarwaddy region and Kyauktan Township, Yangon region of Myanmar

Source: Myanmar Information Management Unit (MIMU)

only 599 samples were entered as data. Among the survey respondents, 377 men- (62.9%) and 222 women-headed farm households (37.1%) were included as survey respondents. Women-headed households were defined as farm households currently under the supervision of women owing to the absence or death of a male head and where farm activities were mostly implemented by women. Data were collected through four steps:

(1) field observation;
(2) validation of selected indicators with key stakeholders;
(3) enumerator's selection and training; and
(4) farm household survey interviews during the period from September to October 2021 in Myanmar.

The enumerators from the targeted villages were selected and trained in both virtual training and pilot surveys, given the political situation in Myanmar. Although this study was conducted in line with the proposed research objectives, a number of limitations still remain. Before the survey, the enumerators were trained and tested with the set of questionnaires in advance. However, their level of understanding of the climate change concepts and the types of questionnaires may not be perfect. Therefore, the KoboToolbox [1] data collection tool was used to collect the field-level data and the data quality was regularly checked through KoboToolbox on a daily base during the survey. The ethical consent form was also prepared and asked for the interviewee's consent to participate in the survey. Only after the respondents were reported to participate the interview was carried out. The research team paid special attention to the norms, values and ethics of community participants and prioritized ethical issues during the research assessment amid the development of COVID-19 pandemic in the region.

2.2 Empirical specification of multinomial logistic regression

Firstly, the study performed a descriptive analysis of the perceptions about climate change, the risks introduced by climate change, the impacts of COVID-19 on farm households and the barriers farmers had to face to apply different farm-level adaptation measures. Next, a multinomial logistic regression was used to analyze the determinants of farmers' choice of adaptation methods. The multinomial logit regression (MLR) model is a discrete choice model and is based on the theory of adoption decision (Ndah *et al.*, 2010). This method was previously used to study the driver for the adoption of climate change mitigation strategies by Deressa *et al.* (2009), Tazeze *et al.* (2012) and Obayelu *et al.* (2014). Following this model, the probability that a farmer *(i)* will choose an adaptation alternative *(j)* from the options could be defined as:

$$Prob\left(Y=\frac{j}{X}\right)=P\left(U_{ij}>\frac{U_{ik}}{X}\right) \tag{1}$$

where 'X' is a vector of explanatory variables. U_{ij} and U_{ik} are the perceived utilities for the farmer **(*i*)** of adaptation *(j)* and **(*k*),** respectively. The response probabilities of the multinomial logit model are:

$$Prob(Y_i=j)=\frac{e^{\beta_j{}'X_i}}{\sum_{k=0}^{j}e^{\beta_j{}'X_i}},\quad j=0,1,2,\ldots\ldots\ldots J \tag{2}$$

where, $\beta_j^{'}$ is a vector of coefficients on each of the independent variables "X." The above equation can be normalized to remove indeterminacy in the model by assuming that $\beta_0 = 0$ and the probabilities of choosing from a set of alternatives can be estimated as:

$$Prob\left(Y_i = \frac{j}{X_i}\right) = \frac{e^{\beta_j' X_i}}{\left[1 + \sum_{h=1}^{j} \left(e^{\beta_k' X_i}\right)\right]}, \quad j = 0, 1, 2 \ldots\ldots J, \quad \beta_j' = 0 \tag{3}$$

The J log-odds ratio of the model is given as:

$$In\left(\frac{P_{ij}}{P_{ik}}\right) = X_i(\beta_j - \beta_k) = X_i'\beta_j, \quad if \quad k = 0 \tag{4}$$

For this model, the independence of irrelevant alternatives (IIA) assumption should hold. Two basic types of tests can be used to see whether the IIA assumption is violated: a choice set partitioning test and a model-based test (Cheng and Long, 2007). Possibilities include the McFadden, Train and Tye Test (McFadden *et al.*, 1981) and the Hausman and McFadden Test (Hausman and McFadden, 1984). The marginal effects of changes in the explanatory variables are usually derived as:

$$\frac{\partial Pj}{\partial Xi} = P_j\left[\beta_j - \sum_{k=0}^{j} P_k\beta_k\right] = P_j(\beta_j - \beta) \tag{5}$$

where $\frac{\partial Pj}{\partial Xi}$ stands for the marginal effects of changes in the explanatory variables. Marginal effects show the change in probability when the predictor or independent variable increases by one unit. Then, the MLR model was also presented as follows:

$$Y_j = \frac{\partial Pj}{\partial Xi} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots\ldots\ldots\ldots\ldots + \beta_{10} X_{10} + ei \tag{6}$$

where Y_j represents the different adaptation strategies applied by the respondents. X_i is the different independent or explanatory variables in the model. In the MLR analysis, the estimation of the model was performed by normalizing one category. In the analysis, "no adaptation" is used as the normalized category or "base category." In the initial run, gender, access to credit services and water sources were added into the model, but they did not have a significant effect on the adaptation choices, and thus, they were dropped. Using traditional tools such as frequency and descriptions to accumulate the source of the indicators from the process of interviewing, group discussions and household surveys were conducted and presented. This study also classifies the constraints and limitations to the choice of adaptation and evaluates the farmers' level of perception related to the changing climate in the coastal areas of Myanmar.

3. Results and discussions

3.1 Farm households' perception of climate change extremes

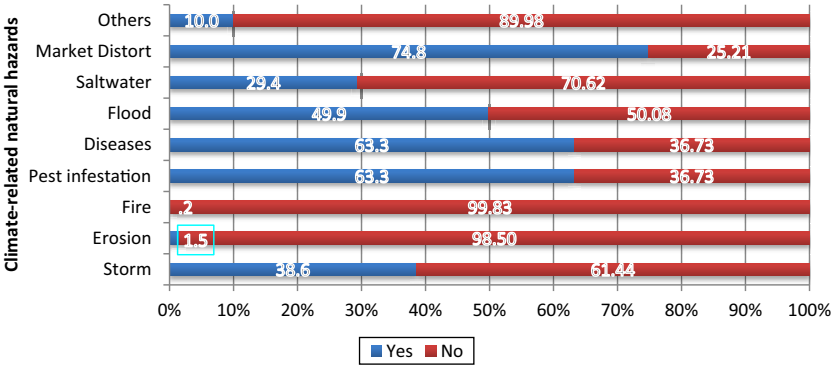
Farm household's perceptions of climate change and its effects were captured with a number of questions using a nominal scale. The questions explore the perception of farm households

about the occurrence of climate change extreme events and its impacts on production over the previous 10 years period (see Figure 2). The study found that market distortions (74.8%), diseases and pest infestations (63.3%) were the main challenges faced by the farm households. This result is in line with the findings of the study by Etana *et al.* (2023) that a market distortion reduces the effectiveness of adaptation strategies and the uptake of the climate change adaptation measures. Flooding and saltwater intrusion into farmland (49.4% and 29.4%) was also reported by most of the farm households. They also reported storms or cyclones occurrence (38.6%), particularly in the premonsoon period between April and June. In this study, farmers perceived the changes of climate, climate variability and climate related extreme events. Therefore, the adaptation process at the farm level is determined by farmers' perceptions of climate change extremes and the adoption of adaptation strategies (Tun Oo *et al.*, 2017).

3.2 Farm households' adopted adaptation strategies

The study also observes climate change adaptation strategies used by farm households in Myanmar. The adaptation strategies used by rice farmers differ significantly from those used by smallholder fish farmers in Myanmar (see Figures 3 and 4). Building embankments (22.39%) and changing to rice varieties resistant to flooding and saltwater intrusion (19.57%) were the most common strategies adopted by farm households. About 16.3% of farm households reported that they did not have any agricultural adaptation strategy. This was followed by adjusting the planting date (13.48%) and brine seed (9.35%) before sowing in the field. This study is consistent with the finding of Terefe (2023) and Zeleke *et al.* (2023) that adjusting planting dates is one of the adaptation strategies that help farmers to adjust the timing of their agricultural activity. And Asravor (2022) found that 28% of farm household did not apply any adaptation strategy to climate change. Therefore, this study found that building infrastructures such as dikes and embankments and changing over to rice varieties suitable and or adaptable to saltwater intrusion are important adaptation measures for most agriculture farm households in the coastline areas of Myanmar. Just 33 farm households (6.84%) adopted traditional farming methods such as basic soil management practices, burning rice straw, manual harvesting and crop management practices.

Aquaculture farm' households adopted net-fencing (*Zar-protect means net-fencing*) as the main strategy (33.91%), which was followed by no adaptation (15.65%) and building



Source: Author's work 2022/ / 2023- own survey 2021

Figure 2.
Farmer's perception of climate-related natural hazards (The *y*-axis shows the different type of natural hazards that occurred over the past 10 years) ($n = 599$ households)

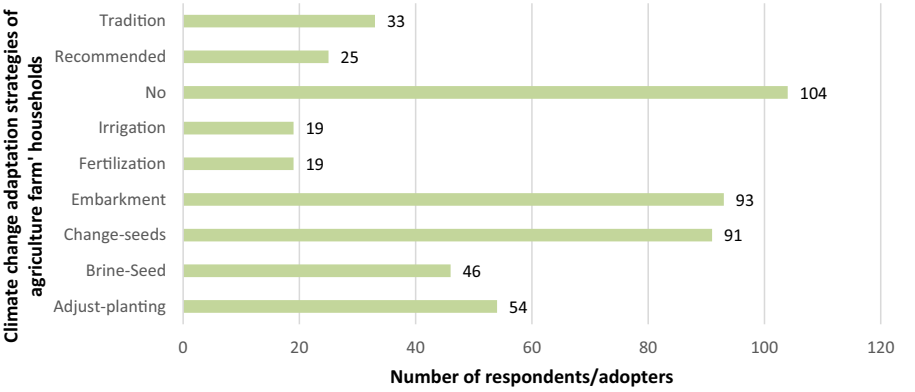


Figure 3.
Agricultural farm-households adopted climate change adaptation strategies ($n = 484$ households)

Source: Author's work 2022/ / 2023- own survey 2021

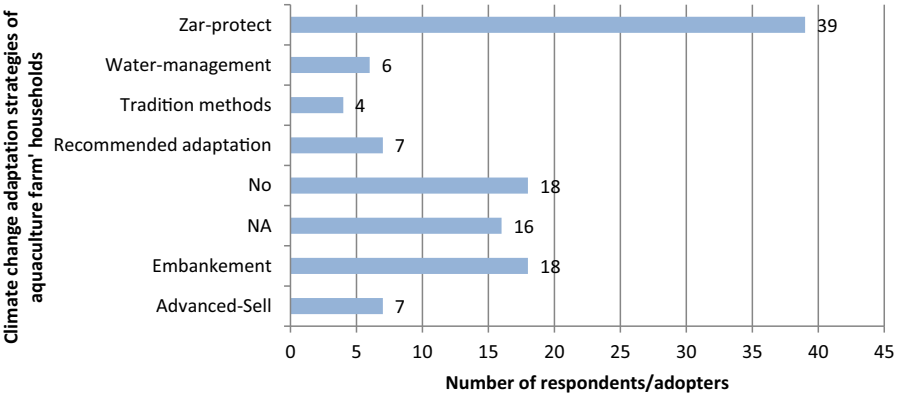


Figure 4.
Aquaculture farm-households adopted climate change adaptation strategies ($n = 115$ households)

Source: Author's work 2022/ / 2023- own survey 2021

embankments (15.65%) (see Figure 4). About 13.91% of farm households reported they were not relevant as they were not doing fish farming at the time. Oparinde (2021) found that embankment building is a widely used adaptation strategy to climate change in the Southwest of Nigeria. This study indicated that the adoption of embankments increased fish farmers' food security. About 3.48% of fish farmers reported that they applied some traditional aquaculture management practices, such as collecting seeds from the natural abundant areas and harvesting any size of fish when needed for private consumption or sale. About 6.09% of smallholder fish farmers reported the application of recommended aquaculture management practices such as collecting seeds from the private or public nursery ponds, water quality management and recommended feeding practices.

3.3 Impact of COVID-19 pandemic on farm households

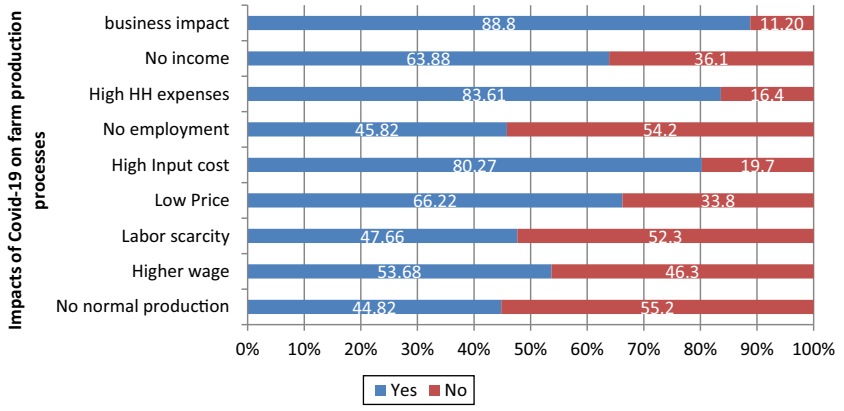
The COVID-19 pandemic posed an additional challenge to farm households because of COVID-19 travel restrictions and health impacts that delayed the agricultural processes.

Although the COVID-19 pandemic affected several sectors of the country, this study only focuses on the impacts on agriculture and aquaculture farm households and production in the coastal areas of Myanmar (see Figure 5). According to the study, the COVID-19 pandemic significantly affected farming and production processes, and it was reported by the majority of farm households (88.8%) as an important stressor. The COVID-19-related travel restrictions delayed transportation of goods and services in the country and involved higher transportation costs in food and farm input distributions. Therefore, 83.61% and 80.27% of farm households reported a rapid increase in household expenses and farm input costs. Studies by Lambrecht *et al.* (2021), International Food Policy Research Institute (IFPRI) and Michigan State University (MSU)' Researchers (2020) found that limited access to farm inputs such as fertilizers and pesticides coupled with higher transportation costs led to higher costs of farm inputs in Myanmar during the COVID-19 outbreak in Myanmar.

As a result, 66.22% of farm households reported a low return on their investments and about 63.88% reported a lack of income from farming activities during the outbreak of COVID-19 in Myanmar. The COVID-19 also posed an additional threat to livelihood activities such as farming, labor availability and employment opportunities for casual laborers or households. This study found that about 47.66% of farm households reported a scarcity of farm laborers and increased payment to farm laborers due to high labor wages. A lack of employment opportunities was also reported by the 45.82% of farm households because their households' members were also faced with a lack of employment opportunities at the farm and nonfarm activities. As a result, 44.82% of farm households reported that livelihood activities and agricultural production were impacted by the consequences of COVID-19-related restrictions in Myanmar and normal farm production of fish and rice crops were affected. Moreover, about 66.22% of farm households reported that they had to face a price decrease for their farm products, which could be due to the deformed market system and lack of incentive to pay a fair price by the buyers such as retailers and brokers during the COVID-19 pandemic in Myanmar.

3.4 Model results and discussions

Table 1 presents the explanatory variables used in the model. The estimated coefficients, marginal effects and *p*-values from the MLR that analyze the determinants of the agricultural



Source: Author's work 2022/ / 2023- own survey 2021

Figure 5. Impacts of the COVID-19 pandemic on agriculture and aquaculture production processes ($n = 599$ households)

Variable	Description of the variables	% (yes = 1)	% (no = 0)
Gender	Gender of household's head (1 = man, 0 = woman)	60.5	39.5
Barrier_Labor	Household reported labor scarcity as a barrier to adaptation decision (1 = yes, 0 = no)	56.6	43.4
Barrier-HighInput	Household reported high input cost as a barrier to adaptation decision (1 = yes, 0 = no)	81	19
Barrier-LowPrice	Household reported low market price as a barrier to adaptation decision (1 = yes, 0 = no)	69.6	30.4
Age	Age of the household's head (1 = HHH with age above 40 years, 0 = HHH with age below 40 years)	75.8	24.2
Education	Education of HHH (dummy, 0 = <secondary education or no-education, 1 = >secondary education)	42.8	57.2
Market-mile	Distance to market (dummy: 0 = <average distance 4.7miles, 1 = >average distance)	53.1	46.9
COVID-Impact-Production	Household reported the COVID-19 impact on farm production (1 = yes, 0 = no)	43.5	56.5
EW-GovPrivate	Household received early warning information from government and private sectors (0 = no, 1 = yes)	30.4	69.6
Remittance	Household received income from remittance (dummy: 0 = no, 1 = yes)	80.8	19.2

Note: HHH = Head of Household
Source: Authors' work 2022/2023 – own survey 2021

Table 1. Empirical specification of the model variables (agriculture farm households)

farm household's adaptation strategies were presented in Table 2. In the analysis, the likelihood ratio statistics as indicated by the chi-square statistics were found to be highly significant in agriculture farm households but not in aquaculture farm households. Before running the model, all the explanatory variables were checked for multicollinearity using the variance inflation factor. This was less than 10(ranges between 1.06 and 6.18), which means that multicollinearity is not a serious problem in the model estimation. The model was also tested for the validity of the IIA by using the Hausman test, and it was found that the odds of any two outcomes are independent of the remaining ones. Therefore, the probability of using a certain adaptation method by a given household is assumed as independent from the probability of taking another adaptation method. The classification matrix was also checked for evaluating the accuracy of the model. The predicted value is the percentage of cases for which our model predicts accurately, the result was 72.048% in agriculture farm households.

The marginal effects or odds ratios of MLR output are also reported and discussed as the expected change in the probability of a particular adapted strategy or method due to a unit change in an independent variable in the model. The chi-square results show that likelihood ratio statistics are highly significant (p-$value = 0.02$) in agriculture farm households. The ability to handle classified outcomes with multiple groups is one of the multinomial logistic regression's key benefits. The model provides probabilities for each category, which improves interpretation and decision-making.

3.4.1 Determinant of the adaptation strategies of agriculture farm households in Myanmar. The MLR model estimated that age, gender, education level, remittance income, loan availability, flood-affected village, saltwater-affected village and access to early warning information had a significant influence on the choice of adaptation measures of agriculture farm households in Myanmar (Table 2). Results can be summarized as follows:

Table 2. Parameter estimates of the multinomial logit regression for climate change adaptation decisions of crop farmers (n = 484 households)

	Changes of varieties ($n = 137$)			Recommended strategies (Irrigation + fertilization) ($n = 63$)			Adjust planting dates and cultivation methods ($n = 53$)			Embankment and soil management ($n = 93$)			Tradition adaptation measures ($n = 33$)		
Explanatory variables	Coeff.	Exp (B)	p-value	Coeff.	Exp (B)	p-value	Coeff.	Exp (B)	p-value	Coeff.	Exp (B)	p-value	Coeff.	Exp (B)	p-value
Gender	0.809	0.445	0.003***	0.705	0.494	0.034**	0.969	0.38	0.007***	1.097	0.334	0.476	1.591	0.204	0.001***
Barrier-LaborScarcity	0.132	1.141	0.643	−0.355	0.701	0.031**	0.09	1.094	0.807	0.257	1.293	0.416	−0.104	0.901	0.818
Barrier_HighInput	−0.221	0.802	0.574	−0.438	0.645	0.057**	0.412	1.509	0.435	−0.447	0.639	0.309	−0.333	0.717	0.601
Barrier_LowPrice	0.316	1.371	0.311	−0.512	1.669	0.210	−0.344	0.709	0.362	0.058	1.060	0.863	1.159	3.186	0.049**
Market-mile (Binned)	−0.106	0.9	0.704	0.196	1.216	0.571	−0.687	0.503	0.069**	0.025	1.025	0.935	−0.122	0.885	0.785
Age (Binned)	−0.368	1.444	0.193	−0.667	1.948	0.052**	−0.003	0.997	0.994	−0.634	1.885	0.041**	−1.054	2.868	0.016***
Education	−0.004	0.996	0.969	0.095	1.099	0.041**	0.109	1.115	0.374	−0.065	0.937	0.056**	0.219	1.245	0.102*
COVID-NoProduction	0.136	1.146	0.638	−0.646	1.907	0.073**	−0.034	0.966	0.929	0.452	1.572	0.153	0.191	1.210	0.067**
EW-GovPrivate	0.286	1.332	0.372	0.285	1.330	0.046**	0.216	1.241	0.056*	−0.307	0.736	0.415	−0.013	0.987	0.979
Remittance-Income	0.16	1.174	0.064*	1.032	2.806	0.047**	−0.084	0.92	0.85	0.096	1.100	0.799	0.698	2.009	0.237
Diagnosis	Base = no adaptation ($n = 104$) Number of obs = 484				Prob > $chi^2 = 0.022$ LR $chi^2 = (72.048)$						Pseudo $R^2 = 0.044$ Log-likelihood = −1,237.81				

Notes: ***Values statistically significant at 0.01 probability level; **values statistically significant at 0.05 probability level; *values statistically significant at 0.10 probability level
Source: Model results (authors' work)

Age. The age of farm household owners is negatively associated with the adoption of climate change adaptation measures in the coastal areas of Myanmar. It means that the older farmers or farmers with over 40 years of age were negatively associated with the adoption of some climate change adaptation measures compared to young farmers with less than 40 years of age. As hypothesized, the study found out that the older farmers were more likely to choose measures related to indigenous methods such as basic soil and water management and recommended adaptation measures with a significant result (respectively, p-*value* = 0.016 and p-*value* = 0.052). This study was consistent with the findings of Gebre *et al.* (2023) that young farmers are more aware of the climate risks and related farm-level adaptation measure than older farmers.

Gender. As was hypothesized, the adoption of climate change adaptation measures of farm households were positively associated to the gender status of farm households. Male farmers were more inclined to adopt climate change adaptation strategies than the female farmers in the study areas. However, male farmers were more likely to choose recommended adaptation measures such as improved water management and fertilizer application. This result is in line with the study conducted by Zeleke *et al.* (2023) who reported that male farmers are most likely to adopt soil and water management practices than female farmers. Bessah *et al.* (2021) found that male farmers are more likely to use agrochemicals as a climate change adaptation strategy often compared to female farmers. Therefore, this study advises further research into the perception differences of climate change adaptation strategies among male and female-farmers as well as gender-based adoption variation analysis.

Education level. Farmers with higher education levels were more likely to choose measures related to recommended adaptation measures such as improved fertilizer application and soil management methods, while those with a lower level of education were more likely to choose measures related to indigenous farming methods and embankment building practices. Sahoo and Moharaj (2022) found that the educated households were more likely to adopt the climate change adaptation strategies than those less educated. Moreover, in a similar study, Do and Ho (2022) found that education of farm households and farmer's belief in climate change are the major factors prompting farm households to adopt climate change adaptation strategies in the Mekong Delta of Vietnam. Therefore, promoting awareness and technological supports through formal and informal trainings can enable farmers to implement the climate change adaptation measures at the farm level.

Barriers to the uptake of adaptation strategies. This study also considered the practical barriers to the adoption and taking up of the farm-level adaptation strategies. Due to the practical barriers such as labor scarcity, and high input costs, it was found that the agriculture farm households are less likely to uptake the recommended farming strategies such as water management and fertilizer application methods. This could be due to the fact that farmers are less likely to invest in farming as a result of rising farm investment costs and labor scarcity. As a result, farmers are more likely to stick to traditional farming measures such as low farm technology investments and utilization of indigenous or traditional crop varieties when the price of their farm products falls. This finding was significant, with p-*value* = 0.049 in traditional adaptation measures.

COVID-19 impacts on production. This study also found out that the COVID-19 pandemic had a substantial impact on farm investment and adaptation decision-making. Farm households applied more traditional farming practices than recommended irrigation and fertilizer application methods and the findings were significant, with p-*value* = 0.073 in recommended farming strategies and p-*value* = 0.067 in traditional adaptation measures. This fact may be due to the lack of farm household incentives to invest in recommended

adaptation measures, as farm input costs rise and the number of farm laborers decreases in the face of COVID-19 outbreak in Myanmar. Therefore, as the adaptation processes shift gradually, the potential of adopting the recommended adaptation measures by the farm households increases when practical barriers are reduced (Tun Oo *et al.*, 2017).

Remittance income. Farmers who received remittances from household members or migrant family members were more likely to pick new crop varieties and improved water management and recommended adaptation methods. This could be due to the lack of a proper credit scheme in the region during the COVID-19 pandemic and the only source of credit was from the migrant family members. The households having access to remittance credit were more likely to adopt climate change adaptation measures than those having none. Therefore, as a post-COVID-19 recovery plan, a proper credit scheme accessible to the farm households should be considered by the private and public financing institutions in Myanmar.

Access to early warning information. Farmers who had access to early warning information were more likely to choose measures related to improved water management and recommended adaptation methods. Gemeda *et al.* (2023) and Terefe (2023) found that access to early warning information motivated farmers to adopt different adaptation strategies and helped farmers to adjust their activities to reduce the risk of climate change. Aung *et al.* (2023) reported that factors such as distance to the market, access to information, awareness of pond maintenance benefits were the key drivers behind the adoption of sustainable farming technologies. Therefore, this study highlighted the relevance of early-warning and information sharing using existing information dissemination channels such as radio, television (TV) and mobile phone applications and so on, to improve the uptake and adoption of climate change adaptation measures by farm households in Myanmar.

3.5 Barriers to climate change adaptation

Climate change poses a significant threat to livelihoods, and farm households are coping with farm-level adaptation measures. However, some barriers limit farm households' choice of climate change adaptation measures. A number of studies have looked into the constraints and barriers to the uptake of climate change adaptation measures at farm level (see more on Deressa *et al.*, 2009; Tessema *et al.*, 2013; Tun Oo, 2018). Unlike the previous studies, this study captured the effects of COVID-19 pandemic aside from the practical farm-level barriers on the uptake of climate change adaptation measures of farm households. The study also explores the reasons for the low adoption of climate change adaptation measures by farm households in Myanmar (see Figure 6) and found out that high input costs associated with the COVID-19 travel restrictions and high fertilizer costs were reported by majority of farm households as the main barrier (81%). Terefe (2023) and Gemeda *et al.* (2023) also indicated that the major barriers in adapting to climate change were the high cost of fertilizers and farm inputs. In this study, low agricultural produce market prices were also cited as a barrier (73%).

Pest and disease infestation associated with changing weather and climate conditions were also mentioned as a barrier limiting the implementation of climate change adaptation measures at the farm level. Gemeda *et al.* (2023) also reported that incidents of crop pest and disease occurred more frequently and were claimed as the major barrier to the adoption of climate change adaptation strategies in farms. Shortage of agricultural labor (52.8%), lack of credit availability (42.4%) and saltwater intrusion associated with flooding (32.4%) were found as the main barriers limiting the potential adoption of adaptation strategies. Zeleke *et al.* (2023) found that the most important barriers were poor access to climate and market information, high cost of irrigation facilities and limited financial capital for effective

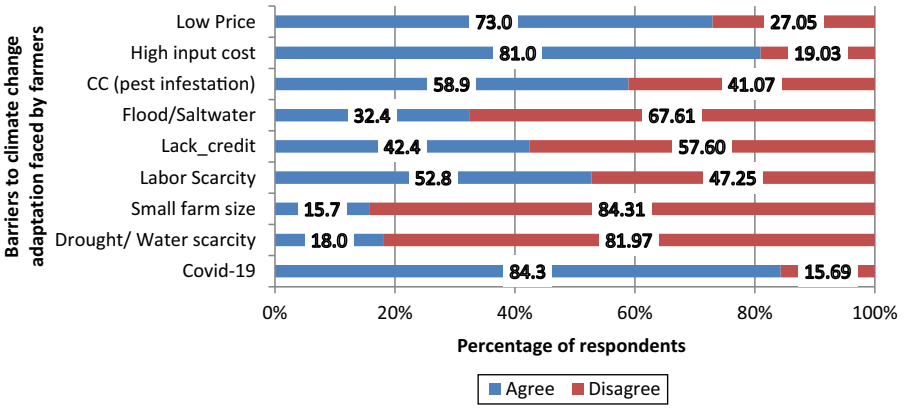


Figure 6.
Barriers or constraints to climate change adaptation ($n = 599$ households)

Source: Author's work 2022/ / 2023- own survey 2021

adaption. Nguyen and Bleys (2023) and Tun Oo *et al.* (2023) indicated that saltwater intrusion was the major difficulty in rice production in the coastal region. Therefore, the majority of agriculture and aquaculture farm households reported that practical farm-level barriers were the major limiting factors in their adoption of climate change adaptation strategies in the coastal areas of Myanmar.

4. Conclusions and recommendations

This study found that agricultural and aquacultural households, regardless of farm-management systems, adopted a variety of farm-level adaptation measures to reduce the impacts of climate change and natural hazards such as flooding and saltwater intrusion. The most preferred adaptation techniques were the embankment building and switching to rice varieties resistant to flooding and saltwater intrusion. Aquaculture farm households, on the other hand, chose net-fencing as primary adaptation option. The adoption of climate change adaptation measures by farm households in Myanmar is influenced by socioeconomic, and institutional factors. The factors that influence farmers' choice of adaptation strategies vary and include characteristics such as age, gender, education level, access to credit and access to early warning information. These findings highlight the importance of promoting education and awareness, facilitating access to credit and strengthening institutional support to enhance the adaptive capacity of farm households in the coastal areas of Myanmar. These findings also suggest that interventions and policies aimed at enhancing the adaptive capacity of farmers need to be context-specific and address the unique challenges faced by farm households, that is assessing the practical farm-level barriers, addressing these barriers as a way to improve the adoption of climate change adaptation measures and considering climate change adaptation measures as a strategy in COVID-19 recovery plan. To improve the adaptive capacity of farmers in Myanmar, a few recommendations have been provided for improved adoption to climate change adaptation measures by farm households in the coastal areas of Myanmar.

4.1 Increase access to credit

This study found out that farmers who have access to credit and remittances from their household's members or migrant workers were more likely to choose measures related to

crop diversification, and recommended climate change adaptation measures. Therefore, policies that boost access to credit for smallholder farmers can assist them in implementing these measures at farm level.

4.2 Improve access to information

Farmers who have access to early warning information were also more likely to choose the recommended adaptation measures. Therefore, policies that improve access to information about climate variation, extreme events and its consequences can assist farmers in making informed decisions regarding the choice of climate change adaptation strategies.

4.3 Promote education through formal or informal trainings

This study also highlighted that farmers with higher education or awareness levels were more likely to choose measures related to crop diversification, water management and recommended climate change adaptation measures. Therefore, policies that encourage education and awareness of rice and fish farmers in Myanmar can aid in the implementation of climate change adaptation measures.

4.4 Determinant of the aquaculture adaptation strategies

The MLR model was also used to assess the factors that influence aquaculture farmer's decisions about climate change adaptation methods. There were no significant model and explanatory variable outcomes detected (p-*value* $= 0.127$). This could be attributable to the low sampling of the aquaculture farm households and the model itself cannot be used with the available data sets (see Appendix Tables A1 and A2). Therefore, it is recommended that additional research be conducted with a larger number of samples and data sets to evaluate the effects of the socioeconomic variables on the choice of climate change adaptation measures by aquaculture farm households.

4.5 Address context-specific challenges

The findings suggest that context-specific adaptation measures are needed to address the unique challenges faced by farmers in different regions. Therefore, policies that consider the specific challenges faced by farmers in different regions can be more effective in enhancing the adaptive capacity of farmers. Overall, these recommendations can help to enhance the adaptive capacity of farmers in Myanmar and enable them to cope with the challenges posed by climate change. This study was only focused on the choice of agriculture and aquaculture-dependent households in two coastal areas of Myanmar and additional studies should be conducted in different parts of the coastal areas taking into account other livelihood sectors and contexts to maximize the understanding of the farmer's choice of climate change adaptation measures and practical barriers to their uptake.

Note

1. https://support.kobotoolbox.org/welcome.html

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Appendix

Variable	Description of the variables	% (yes = 1)	% (No = 0)
Gender	Gender of household's head (1= man, 0= woman)	73	27
Barrier_Labor	Household reported labor scarcity as a barrier to adaptation decision (1=yes, 0= no)	36.5	63.5
Barrier-HighInput	Household reported high input cost as a barrier to adaptation decision (1=yes, 0= no)	80.9	19.1
Barrier-LowPrice	Household reported low market price as a barrier to adaptation decision (1=yes, 0= no)	87	13
Age	Age of the household's head (1=HHH with age above 40 years, 0=HHH with age below 40 years)	38.3	61.7
Education	Education of HHH (dummy, 0= < secondary education or no-education, 1= > secondary education)	60.9	39.1
Market-mile	Distance to market (dummy: 0= < average distance 4.7miles, 1= > average distance)	56.5	43.5
COVID-Impact-Production	Household reported the COVID-19 impact on farm production (1=yes, 0= no)	49.6	50.4
EW-GovPrivate	Household received early warning information from government and private sectors (0=no, 1=yes)	54.8	45.2
Remittance	Household received income from remittance (dummy: 0= no, 1= yes)	17.4	82.6

Source: Author's work 2022/2023- own survey 2021

Table A1. Empirical specification of the model variables for aquaculture households

Explanatory variables	Embankment and soil management practices			Water Management Practices			Recommended Aquaculture Practices		
	Coeff.	Exp (B)	*p*-value	Coeff.	Exp (B)	*p*-value	Coeff.	Exp (B)	*p*-value
Education	−0.214	0.807	0.312	−0.708	0.493	0.122	−0.192	0.825	0.513
EW-GovPrivate	0.037	1.037	0.948	0.616	1.851	0.525	0.251	1.285	0.742
COVID-NoProduction	0.68	1.973	0.21	1.133	3.105	0.224	−1.246	0.288	0.146
Gender	−0.036	0.965	0.95	−0.866	0.421	0.395	−1.959	0.141	0.117
Difficulties-LaborScarcity	−0.152	0.859	0.797	−0.357	0.7	0.703	1.089	2.970	0.219
Difficulties-HighInput	−0.928	0.395	0.151	−1.616	0.199	0.102	0.401	1.494	0.698
Remittance-Income	−0.724	0.485	0.266	−1.372	0.254	0.225	−0.612	0.542	0.548
Barrier_LowPrice	−0.439	0.645	0.396	0.525	1.690	0.588	−0.947	0.388	0.179
Age (Binned)	−0.553	0.575	0.298	−1.800	0.165	0.089	−0.621	0.537	0.405
Market-mile (Binned)	0.984	2.674	0.137	0.848	2.335	0.439	0.505	1.657	0.574
Diagnosis	Base= no adaptation Number of Obs= 115			Prob> chi^2= 0.127 Log-likelihood = 226.753			Pseudo R^2= 0.116 LR chi^2 = (31.482)		

Notes: ***Values statistically significant at 0.01 probability level; **values statistically significant at 0.05 probability level; *values statistically significant at 0.10 probability level

Source: Model results (author's work)

Table A2. Parameter estimates of the multinomial logit regression for climate change adaptation decisions of aquaculture households (n=115)

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