AQUACULTURE FARMERS' ECONOMIC RISKS DUE TO CLIMATE CHANGE: EVIDENCE FROM VIETNAM

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ABSTRACT

Climate change poses a serious threat for aquacultural productivity. Employing the Autoregressive Distributed Lag (ARDL) model, this research aims to evaluate the economic impact of climate change on aquaculture in Vietnam, drawing on time series data from 1981 to 2013 and including aquaculture yield, acreage, investment, labor, temperature, rainfall, and damage costs to aquaculture caused by natural disasters. The results show that aquaculture yield depends not only on the current value of inputs, but also on their lag values and the yield itself. The results also show that rainfall, storm surges and tropical cyclones negatively affect aquaculture production. After any natural disaster, it takes at least two years to recover from the repercussions for productivity and return to the previous norm. To reduce the vulnerability of aquacultural communities, this study suggests that the state could establish a climate resilience fund specifically for small and medium-scale aquaculture farmers, providing special financial support for those affected by natural disasters.

KEY WORDS

climate change, ARDL model, aquaculture, vulnerability, Vietnam

JEL CODES

C22, D24, F63, O47, O53, Q22, Q54

1 INTRODUCTION

Likely to be seriously affected by climate change, Vietnam is one of the most vulnerable countries in the world (Yusuf and Francisco 2009; Minderhoud et al., 2019). Vietnam's coastal region spans about 3,000 km populated by more than 20 million people, most of whom are low-income and dependent mainly on aquaculture or agriculture. The multidimensional impact of climate change can be observed in coastal areas, and damage due to extreme

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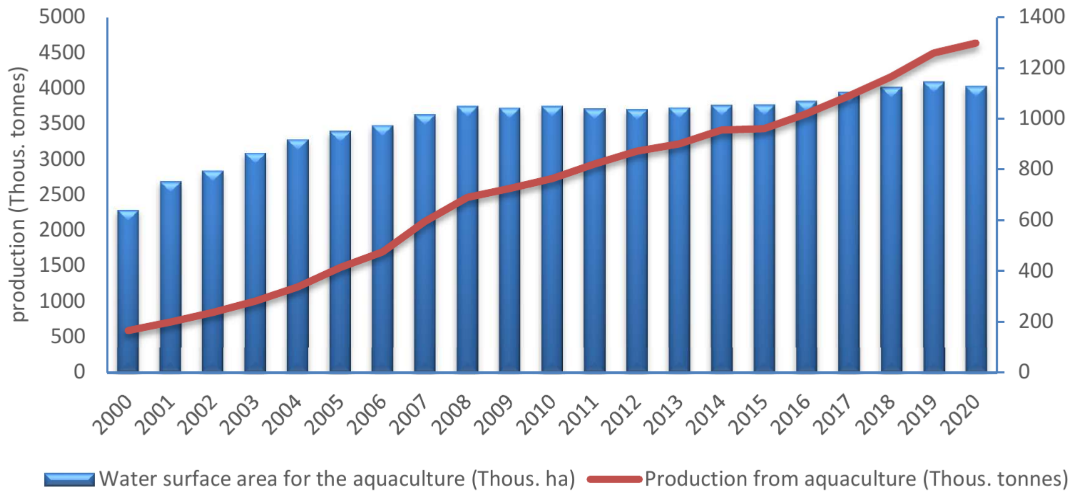

Fig. 1: Production of aquaculture in 2000–2016 (GSO, 2020)

weather events, such as hurricanes, floods, and tidal surges, are becoming increasingly frequent (McElwee et al., 2017; Bangalore et al., 2016). Arndt et al. (2015) estimate that in Vietnam overall, climate change is likely to reduce national income by between one and two percent by 2050. Rising sea levels and increasingly violent cyclones will be the main causes for these economic losses.

A long coastline and tropical weather provide Vietnam with ideal conditions for aquaculture which, in fact, is one of the country's major foreign exchange earners. Its most important seafood products are shrimp and pangasius fish which Vietnam exports to many countries, including Europe, Japan, and the USA. Over the last 20 years, seafood production from aquaculture in Vietnam has increased even though the total water surface area for aquaculture has remained stable (Fig. 1). In 2020, Vietnam earned 3.2 billion USD from the export of seafood products (VASEP, 2021).

However, fish production from aquaculture is frequently affected by climate change and climate-related natural disasters. Not only has climate change significantly altered the intensity and frequency of rainfall, temperature and cyclones, but it has also contributed to rising sea-levels in Vietnam (IPCC, 2014).

The Vietnamese aquaculture and fisheries sector also faces business risks from climate change. According to the latest report (2012) made by DARA (an independent NGO) and the Climate Vulnerable Forum (CVF), Vietnam ranked highest among countries where fisheries losses due to climate change are at a threatening (red warning) level, totaling approximately USD 1.5 billion in 2010, a figure that will increase to USD 25 billion by 2030 (DARA and CVF, 2012). The annual average temperature in Vietnam rose by 0.5 to 0.7 °C, and precipitation also evidenced change by periods and regions, though not by significant amounts (MONRE, 2008).

Furthermore, in a disaster-prone country the Vietnamese aquaculture sector has experienced product loss and property damage almost every year due to coastal storm surges (CCFSC, 2017), see Fig. 2. The highest number of storms over the past 20 years occurred in 2017, resulting in damage to 60,400 ha of aquaculture area and the loss of 76,500 aquaculture cages. Total economic losses due to storms in 2017 totaled approximately USD 2.63 billion (CCFSC, 2017).

A World Bank study (2010) reported that if no strategy was worked out to mitigate risk from climate change in the Mekong Delta region, by 2020 the income of pangasius farmers (Vietnam is one of the foremost countries in pangasius production in the world) might decline by USD 120,000 per hectare and that

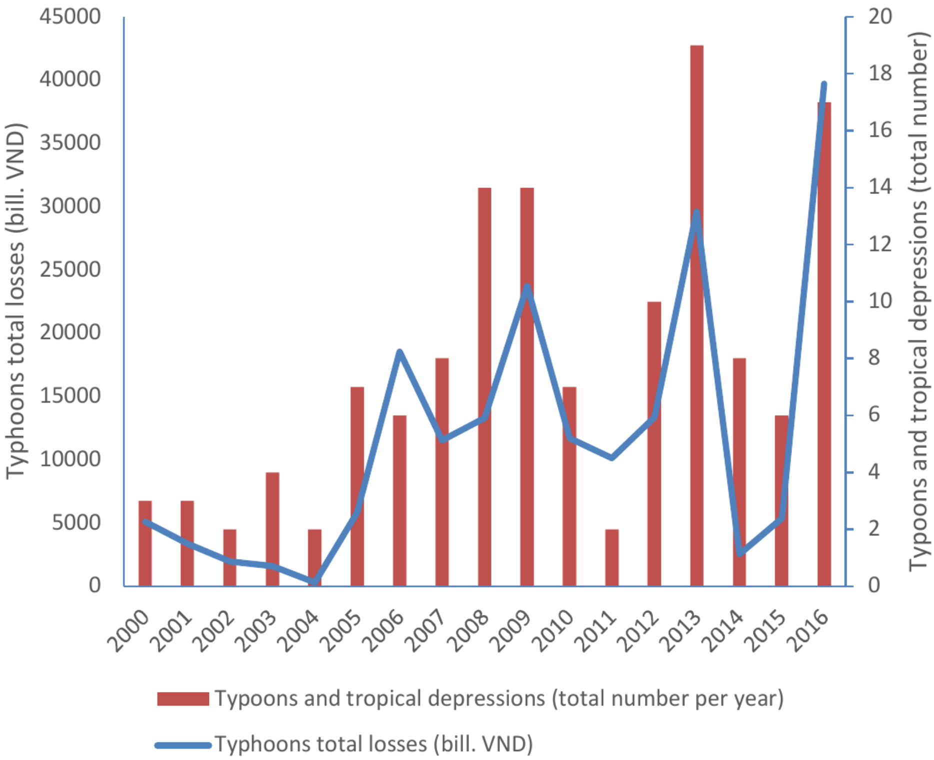

Fig. 2: Tropical typhoons and their consequences on Vietnamese aquaculture sector

of shrimp farmers by about USD 5,000 per hectare, eventually resulting in income losses of up to USD 38,000 per hectare by 2050. Furthermore, costs for climate change mitigation in shrimp culture may increase due to the rising cost of pumping water, raising the height of dikes and constructing new drainage systems. These extra costs for shrimp farms could account for about 2.4% of total annual costs (covering the period 2010–2050; see World Bank, 2010).

However, the above-mentioned studies offer only a limited qualitative assessment, for example identifying vulnerabilities, or they provide a quantitative small-scale evaluation at the household or communal levels, but they do not quantify the economic impact of climate change on aquaculture at the national level.

The key objective of this study is to evaluate the economic risks of climate change for aquaculture in Vietnam by using the ARDL model. The basic assumption is that farmers maximize their aquaculture production by using a combination of different inputs. To achieve this objective, our research raises the following two questions:

1. What are climate change risk factors that affect aquaculture production in Vietnam?
2. How can we quantify the economic risks of climate change for the aquaculture sector in Vietnam?

This paper is structured as follows: Section 2 presents a literature review, the following section describes the methodology used, the results are presented in Section 4 and Section 5 discusses the implications of the results and potential policy measures.

2 LITERATURE REVIEW

Climate change appears to be one of the most influential risk factors for human society. Several studies have shown that climate change and its effects influence environmental and economic factors, and directly and indirectly affect people's lives (Stern, 2007; Heal and Millner, 2014; Kahn, 2016). Vulnerability to climate change has three key elements: the probability of adverse events, their severity, and the capacity to respond to vulnerability (adaptation capacity). Stern (2007) estimates that if countries take no action to mitigate natural disasters or adapt to them, the overall costs of climate change will be the equivalent of losing 5–20% of global GDP each year.

Meanwhile, the cost of acting to reduce greenhouse gas emissions and avoid the worst effects of climate change can be limited to around 1% of global GDP each year. Therefore, an assessment of the effects of climate change is not a country-specific issue but rather demands global action. Sustainable development may be the best way to combat the effects of climate change on human society. The term "sustainable development" includes poverty reduction, human development, including health and job-oriented education, and sustainable environmental management. The United Nations puts heavy emphasis on the implementation of UN SDGs (sustainable development goals) but achieving these goals is always challenging for developing nations. Not only are their resources and capabilities limited but also many of them are highly vulnerable to climate change.

The literature survey shows that several past studies have focused on the risks of climate change for aquaculture productivity, farm income and farmers' livelihoods (World Bank, 2010; Chen, 2011; Ha, 2011; Narita et al., 2012). In their study, for instance, Narita et al. (2012) performed a partial-equilibrium analysis to estimate the global and regional economic costs resulting from the loss of production of mollusks due to ocean acidification. The study revealed that economic losses could total more than 100 billion USD by 2100. Climate change has a tremendous impact on the physicochemical parameters of water (e.g., temperature, salinity, rainfall, dissolved oxygen, sedimentation, and pH) which largely determine the productivity of an aquacultural pond. Evidence shows, for example, that increased water temperature and CO_2 emissions have enormous negative impact on the reduction of dissolved oxygen concentration, increases in ocean acidification, and the reduction of plankton production, which in turn affect the growth rate of fishes and production (Hargreaves and Tucker, 2003; Edwards and Richardson, 2004; Morrill et al., 2005; Allison et al., 2009).

Some studies make use of modeling to quantify the impact of climate change on the world's fisheries. In 2011, research carried out by the Economic Commission for Latin America and the Caribbean – ECLAC (2011) employed econometric models to assess the relationship between fisheries' production (including aquaculture and capture) and factors such as seafood export prices, sea surface temperature and mean annual precipitation. Their results indicated that sea surface temperature and average rainfall were inversely proportional to aquaculture production in Guyana. Losses to the fisheries sector by 2050 according to an A2 scenario would be $15 million (at a discounted rate of 4% per year) to $34 million (with a discount rate of 1%). According to a B2 scenario, estimated losses by 2050 would be $12 million (discount, 4%) to $20 million (discount, 1%). As aquaculture is heavily exposed to environmental conditions and production largely depends on various climatic factors, climate change has a severe impact on aquaculture. Accordingly, aquaculture is a riskier business in comparison with other agro-businesses (Ahsan and Roth, 2010; Ahsan, 2011).

3 METHODOLOGY AND DATA

This research utilizes the Autoregressive Distributed Lag (ARDL) model to build a model for evaluating the risks of climate change on aquaculture in Vietnam. The ARDL model aims to describe the relationship between the inputs and outputs of the production process. It presents the maximum number of outputs from the use of any combination of certain inputs. To quantify the effects of climate change on aquaculture, the ARDL model used in this

Tab. 1: Data description (1981–2013)

Variable	Observations (years)	Maximum value	Minimum value	Mean value	Standard deviation
P = Ln(Produce)	33	15.021	12.101	13.375	0.965
A = Ln(Acreage)	33	13.908	12.346	13.336	0.465
K = Ln(Capital)	33	14.609	10.807	12.935	1.313
L = Ln(Labor)	33	14.503	12.179	13.312	0.869
Dam = Ln(Damage)	33	11.837	6.172	9.274	1.199
Temp	33	26.67	22.96	25.572	0.696
Rainfall	33	2288.6	1311.33	1790.072	249.573
Typhoon	33	5	0	1.485	1.302
Depression	33	5	0	1.364	1.365

Tab. 2: Database description

Variable	Description	Source
$Produce_t$	Aquaculture yield in year t (tonnes)	"Vietnam fisheries sector in 50 years", Vietnam Institute of Fisheries, Economics and Planning; Provincial agricultural and rural development database, Planning Department of the Ministry of Agriculture and Rural Development
$Acreage_t$	Aquaculture acreage in year t (hectares)	"Vietnam fisheries sector in 50 years", Vietnam Institute of Fisheries, Economics and Planning; Provincial agricultural and rural development database, Planning Department of the Ministry of Agriculture and Rural Development
$Capital_t$	Total capital investment in the aquacultural sector in year t (million Vietnamese Dong)	"Vietnam fisheries sector in 50 years", Vietnam Institute of Fisheries, Economics and Planning
$Labor_t$	Total number of laborers in the aquacultural sector in year t (persons)	"Vietnam fisheries sector in 50 years", Vietnam Institute of Fisheries, Economics and Planning
$Damage_t$	Acreage of ponds damaged due to natural disasters in year t (hectares). Missing data is estimated by the GROWTH function in MS Excel, expressing the exponential relation between the total number of typhoons and damaged acreage.	Data from the Standing Office of the Central Committee for Flood and Storm Control (1989–2009)
$Tempt_t$	Average air temperature in year t (°C)	Database of the Ministry of Agriculture and Rural Development
$Rainfall_t$	Average precipitation in year t (mm)	Database of the Ministry of Agriculture and Rural Development
$Typhoon_t$	Number of typhoons (wind speed > 100 km/h) in year t	Database of the Ministry of Agriculture and Rural Development
$Depression_t$	Number of tropical depressions in year t	Data from the Ministry of Natural Resources and Environment
D_1	Governmental fisheries export policy in 1990; D_1 has the value of 1 for 1990–2013 and 0 for earlier periods	The authors have defined this variable
D_2	Renovation period; D_2 has the value of 1 for 1986–2013 and 0 for earlier periods	The authors have defined this variable

study describes the relationship between outputs and inputs, including traditional factors such as yield, capital, and acreage, and some additional climate change factors. The ARDL model has the following form:

$$\begin{aligned}\ln(\text{Produce}_t) = \beta_0 + \beta_1\, T + \\ + \beta_2 \ln(\text{Acreage}_t) + \\ + \beta_3 \ln(\text{Capital}_t) + \\ + \beta_4 \ln(\text{Labour}_t) + \\ + \beta_5 \ln(\text{Damage}_t) + \\ + \beta_6\, \text{Temp}_t + \beta_7\, \text{Rainfall}_t + \\ + \beta_8\, \text{Typhoon}_t + \\ + \beta_9\, \text{Depression}_t + \\ + \beta_{10}\, D_1 + \beta_{11}\, D_2 + \epsilon_t, \end{aligned} \quad (1)$$

where Produce_t – aquaculture yield in year t (tonnes); T – time trend; Acreage_t – acreage of aquaculture in year t (hectares); Capital_t – total capital investment in the sector in year t (million Vietnamese dong); Labor_t – total number of employees in the sector in year t (persons); Damage_t – acreage of damaged ponds due to natural disasters in year t (hectares); Temp_t – average temperature in year t (°C); Rainfall_t – average precipitation in year t (mm); Typhoon_t – number of typhoons with a wind speed of more than 100 km/h in year t; Depression_t – number of tropical depressions in year t. Dummy is a proxy for policy, including D_1 – governmental fisheries export policy in 1990; D_1 has a value of 1 for 1990–2013 and a value of 0 for earlier periods; D_2 – renovation period; D_2 has a value of 1 for 1986–2013 and a value of 0 for earlier periods; β_i – empirical coefficients ($i = 0, 1, 2, \ldots, 11$).

Time series data for 1981–2013 were collected from various sources, presented in Tab. 1 and 2.

In a time-series model, the value of the dependent variable (aquacultural yield) in a given year may depend on those of the previous years, and the values of the independent variables in previous years may also affect the aquacultural yield in the current year. Consequently, the ARDL (autoregressive distributed lag) model is applied to express these dependences. The model has the following form:

$$\begin{aligned} Y_t = v + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \\ + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_q X_{t-q} + \\ + u_t, \end{aligned} \quad (2)$$

in which Y_{t-p} and X_{t-q} are the lags p and q years of Y_t and X_t respectively, and u_t is white noise.

Tab. 3: Tests of lag length for variables (p-values in paretheses)

	Lag 1	**Lag 2**
P	27.925 (0.0009)	3.112 (0.959)
A	27.709 (0.001)	10.718 (0.296)
K	10.097 (0.343)	7.57 (0.578)
L	43.654 (0.0000)	28.39 (0.0008)
Dam	3.682 (0.931)	4.602 (0.868)
Temp	3.894 (0.918)	5.852 (0.755)
Rainfall	1.278 (0.998)	4.798 (0.852)
Typhoon	3.494 (0.941)	3.632 (0.934)
Depression	4.956 (0.838)	7.841 (0.550)
Joint	400.972 (0.000)	382.235 (0.000)

In many years, aquacultural yield is not affected by all possible factors. We choose the variables for the model depending on the lags of such variables as aquaculture acreage, capital investment, labor, damaged pond acreage, the number of typhoons and tropical depressions. Since there is only a small number of observations, the maximum number of lags should be 2. To identify the lag length of the model, we employ lag (−2) with independent endogenous variables. The results show that lag (−2) is appropriate (Tab. 3). We continue by choosing he optimal lag length for the model based on AIC with 2 lags.

4 RESULTS

Stationarity is an important assumption in time series analysis techniques. The stationarity test aims to determine whether a time series is independent of time. A series is stationary if its statistical properties remain unchanged over time. The ADF test (Augmented Dickey-Fuller) can be used to identify the stationarity of a time series. Based on SIC for lag 8, the ADF tests give the results for the stationarity of the yield series. These results show that the ADF statistic is 1.388, which is larger than the 5% critical value (−2.957). Therefore, we cannot reject the null hypothesis of a unit root, and the yield series may be integrated of order one $I(1)$.

Using a similar ADF test based on SIC for lag 8, we have the stationarity results for the depression series. These show that the ADF value is −3.198, which is smaller than the 5% critical value of 5% (−2.957). Therefore, we may conclude that the series is integrated of order zero $I(0)$. Similar tests reveal that the time series on the number of typhoons, damaged pond acreage and rainfall are also integrated of order zero. We choose the optimal lag length for the model based on AIC. The results indicate that lag 2 is optimal in the AIC test, therefore, we run the model regression for lag 2. To obtain the final, more statistically significant model, we drop some variables that have low absolute t values ($t < 1$). The Breusch-Godfrey test (Breusch, 1978) for autocorrelation gives the Chi-square p-value of 0.2275, which is larger than $\alpha = 0.05$, i.e., the model has no autocorrelation problem. We run the model regression for the final selection yielding the estimates shown in Tab. 4.

Tab. 4: Estimates for the optimal lag length

Variable	**Estimate (standard deviation)**
Constant	12.297** (2.966)
T	0.073** (0.017)
A	−0.225 (0.180)
A(−2)	−0.397** (0.137)
K(−2)	0.043 (0.041)
L	0.262 (0.273)
L(−2)	0.384** (0.134)
Temp	−0.047* (0.025)
Rainfall	−0.00014* (0.00006)
Dam	0.039* (0.015)
Dam(−1)	−0.020* (0.011)
Dam(−2)	0.027* (0.014)
Typhoon	0.032* (0.011)
Typhoon(−1)	0.019 (0.011)
Typhoon(−2)	0.044** (0.011)
Depression	−0.012 (0.013)
Depression(−1)	0.042** (0.013)
Depression(−2)	0.039** (0.011)
D_1	−0.360*** (0.061)
D_2	0.088 (0.119)
R^2	0.9991
F statistic	648.4
DW statistic	2.24

Note: The dependent variable is Ln(Produce), $n = 31$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

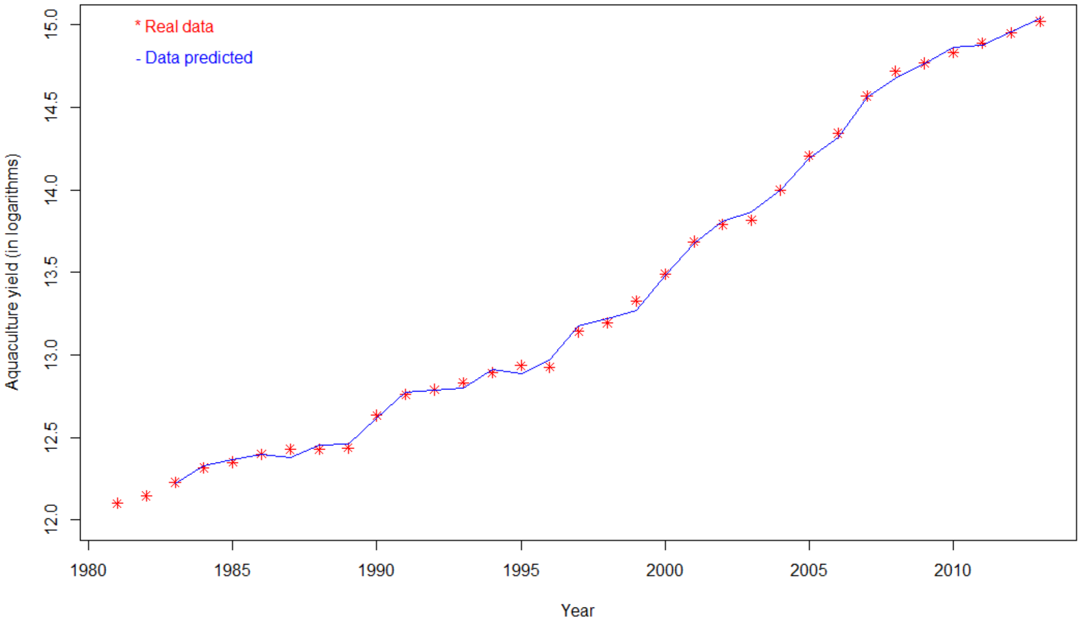

Fig. 3: Original and estimated aquaculture production

The final model for evaluating the impact of climate change on the aquacultural sector in Vietnam is as follows:

$$
\begin{aligned}
\ln(\text{Produce}_t) = 12.297 + 0.073\,T - {} \\
- 0.225 \ln(\text{Acreage}_t) - {} \\
- 0.397 \ln(\text{Acreage}_{t-2}) + {} \\
+ 0.043 \ln(\text{Capital}_{t-2}) + {} \\
+ 0.262 \ln(\text{Labor}_t) + {} \\
+ 0.384 \ln(\text{Labor}_{t-2}) - {} \\
- 0.047\ \text{Temp}_t - {} \\
- 0.00014\ \text{Rainfall}_t + {} \\
+ 0.039 \ln(\text{Damage}_t) - {} \\
- 0.02 \ln(\text{Damage}_{t-1}) + {} \\
+ 0.027 \ln(\text{Damage}_{t-2}) + {} \\
+ 0.032\ \text{Typhoon}_t + {} \\
+ 0.019\ \text{Typhoon}_{t-1} + {} \\
+ 0.044\ \text{Typhoon}_{t-2} - {} \\
- 0.012\ \text{Depression}_t + {} \\
+ 0.042\ \text{Depression}_{t-1} + {} \\
+ 0.039\ \text{Depression}_{t-2} - {} \\
- 0.360\, D_1 + 0.088\, D_2 \qquad (3)
\end{aligned}
$$

To assess the quality of the estimated model, we have drawn the graph with original and estimated production in Fig. 3. The predicted production fits well with the real data.

Results from the estimated model indicate that besides the contribution of production inputs, including aquaculture area, investment capital, and labor, factors reflecting climate change (including damage caused by natural disasters, storms, and tropical depressions) also have an impact on aquacultural production. These factors have either positive or negative effects and can last for 1 to 2 years. The model shows that a 1% increase in acreage will reduce the yield two years later by 0.397%. Growth of 1% in the number of employees raises aquaculture yield by 0.262% in the same year and by 0.384% in the following two years. If the average temperature rises by 1 °C, aquaculture yield declines by 4.7%.

Rainfall also adversely affects aquaculture. If average rainfall goes up by 100mm, yield decreases by 1.4% accordingly. The model also indicates that if damage to acreage increases by 1%, fish production will rise 0.039% in the current year, then decline 0.02% the following year. If the number of tropical depressions increases by 1 in a given year, output will fall 1.2% in that year, then go up 4.2% and 3.9% in the next two years, respectively. A rise in the number of typhoons (> 100 km/h) by 1 will raise aquacultural yield by 1.9% and 4.4% respectively in the following year and the year after that.

5 DISCUSSION AND CONCLUSIONS

Aquacultural yield is influenced by many factors, including environmental factors induced by climate change and their lags. This study reveals that the aquacultural acreage is one of the important factors. Extending water surface acreage increases yield. However, as per the model used in this research, a 1% increase in acreage will result in a decrease of 0.397%. in yield two years later. The reason may be shortcomings in planning and management, inadequate technical and technological conditions for farming a large acreage, and output scale. Investment capital and labor have a positive impact on aquaculture production. If the number of employees grows by 1%, aquacultural yield will rise 0.262% in the same year and 0.384% in the following two years. Growth in labor increases aquacultural yield, raising people's incomes and attracting more workers to engage in this sector.

Environmental factors generally have a negative impact on aquaculture production. Temperature is a very important factor affecting the growth of aquatic species. If the average temperature rises by 1 °C, aquacultural yield declines by 4.7%. Rainfall also may adversely affect aquaculture. If average rainfall goes up by 100 mm, yield will decrease accordingly by 1.4%. Heavy unseasonal rainfall causes inundation, changing the salinity of aquaculture ponds and lakes. Frequently occurring natural disasters result in a decline in aquacultural production, represented by the acreage of damaged ponds. However, the model indicates that if there is a 1% increase in damaged acreage, fish production will rise 0.039% in the current year, but then decline by 0.02% the following year. The reason may be the additional investment of capital and technology to compensate for the damage and to expand production. But if the damage continues, recovery work becomes difficult, and the investment will be inefficient. There is also an indirect effect from cyclones and storm-surges on the productivity of aquaculture ponds because a cyclonic event changes the quality of aquatic habitat and ecosystem productivity (Edwards and Richardson, 2004; Hall-Spencer et al., 2008).

Due to climate change, there will be an increasing number of severe storms and tropical depressions. If the number of tropical depressions increases by 1 in a given year, output will fall 1.2% in that year, then rise by 4.2% and 3.9%, respectively, in the following two years. A rise in the number of typhoons (> 100 km/h) by 1 raises aquacultural yield by 1.9% and 4.4%, respectively, in the following year and the year after, as noted in this study.

Aquaculture farmers' incomes are often higher than those of others in the rural population, but earnings from aquaculture are highly uncertain and not evenly distributed within the sector. Climate change results in more uncertainty in farm production and in the physical structure of aquacultural ponds, and so in overall farm income. There is no doubt that natural disasters, like tropical storm surges and cyclones, cause direct damage to aquaculture production not only in the year in which a disaster takes place but also results in continuing losses during the next 2–3 years and even longer. These are the key reasons behind the rural population's higher vulnerability and lower adaptive capacity to recover from disaster.

After any natural disaster, the recovery phase is crucial, and action is needed to return to a state of normality. If someone asks the question, how can an aquaculture farmer recover the economic losses incurred as the result of a natural calamity, the answer is not simple because the capacity to recover depends on many factors, especially on the individual farmer's financial situation and proper mitigation strategies. It is obvious that additional capital is essential to recover production losses and restart an aquaculture business in the aftermath of any climatic disaster. To recover from sudden economic shock by securing additional capital is always a major challenge for small-scale farmers. Ahsan's study (2011) noted that in Bangladesh, it is very difficult for small-scale aquaculture farmers to recover their economic losses consequent on extreme weather conditions and disasters because with their lack of proper collateral, these farmers have very limited capital and greatly restricted access to formal credit systems. The lack of financial and political support after weather shocks is also considered to be a major hindrance in the socio-economic situation of small and medium-scale aquaculture farmers in developing countries.

In Vietnam, small-scale farmers face similar challenges. Additional capital, improved technology, and strengthening the environmental monitoring and warning system can contribute significantly to enhancing the adaptive capacity of aquacultural farmers to mitigate their production and income losses. An individual farmer (especially the small-scale farmer) in a developing country like Vietnam does not have these resources. Consequently, a supportive public policy is essential so that small-scale farmers can adapt to extreme weather conditions.

This research argues that since climate change is a global phenomenon, a determined initiative on the part of the Vietnamese government will not suffice to reduce the negative impact of climate change on aquaculture business. An effective climate-risk mitigation policy always requires a global response through multinational collaboration, negotiation and joint effort since the contribution of an individual country is not enough to fight climate change (Ahsan and Brandt, 2014).

This study uses short time series data from 1981–2013, which may be a limitation for analysis. As in other developing countries, however, the database for Vietnam is not very rich since the country only started to collect data in 1981. To improve the results from the model, future studies could aim to collect additional information to make up for the missing data and increase the number of observations for analysis and testing.

The ARDL model is used in the study to measure the impact of climate change on the aquacultural sector in Vietnam. The results show that rainfall, storm surges and tropical cyclones negatively affect aquaculture production. After any natural calamities, it takes at least two years to recover from the shock to productivity and return to the previous normal situation. However, farmers' capacity to recover largely depends on the availability of additional capital to reinvest in the farm, a steady supply of inputs at regular market prices, and labor. Therefore, additional institutional support, such as easy access to credit at low interest rates and consultancy services from government field officials, is necessary for at least 2–3 years to strengthen aquacultural farmers' ability to deal with risk and economic loss due to cyclones and storm surges. To reduce the vulnerability of aquacultural communities, this study suggests that the state could establish a climate resilience fund especially for small and medium-scale aquaculture farmers, to provide those affected by natural disasters with special financial support.

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