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Climate Change and Farmers' Adaptation Strategies: The Case of Rice Producers in Nghe An Province, Vietnam

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Abstract

This research aimed at assessing climate trends and adaptation strategies to the impacts of climate change on rice producers in Nghe An province. For the first objective, multiple graphs, the Mann–Kendall test, and Sen’s Slope test were employed to analyze the secondary data of rainfall, temperature, and rice yield in Nghe An from 1995 to 2019. The results showed that the rice productivity of Nghe An increased over the 25-year period, annual rainfall decreased in the winter-spring season, and annual temperature increased in the summer-autumn season. For the second objective, primary data were collected by conducting household surveys of 396 households in Nghe An province. Sixty-two percent of farmers did not adopt any adaptive strategies, while other strategies included changing the planting schedule, growing stress-tolerant crops, improving irrigation practices, and utilizing fertilizer and other good practices. Multivariate probit regression (MVP) was employed to analyze the factors affecting the adaptation strategies of households in the study area. The results of MVP showed that age, education, gender, household size, farm size, cooperative, farmer organization, extension services, access to credit, access to irrigation, rainfall, and living in Quynh Luu or Dien Chau significantly affected the farmers’ choice. The results implied that farmers can obtain advanced technology, social learning, and community practices by participating in farmer organizations and cooperatives. In specified area, local authorities should invest in improving irrigation systems, practicing land consolidation, practicing special farming techniques, and providing timely weather forecasts for enhancing farmers’ resilience.

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Keywords

Climate change, rice, adaptation strategy, multivariate probit, Nghe An

Introduction

Climate change relates to increasing temperatures and extreme rainfall, which may influence agriculture around the world due to its dependence on environmental factors, especially in tropical regions (Chandio *et al.*, 2021a; 2021b; Islam *et al.*, 2021; Zougmoré *et al.*, 2021). Changes in the time and length of seasons, increased temperatures, and rainfall fluctuations may increase the frequency and intensity of droughts, floods, and incidences of pests and diseases (Ahmad *et al.*, 2017; Food and Agriculture Organization of The United Nations - FAO, 2019; Bhusal *et al.*, 2020). The combination of extreme rainfall and strong winds may cause physical damage to plants and excessive water in their roots, which also increases the occurrences of some diseases (Ahmad *et al.*, 2017). High temperatures may reduce soil moisture and soil fertility, leading to the degradation of land quality (Ahmad *et al.*, 2017; Williams *et al.*, 2019; Baruah *et al.*, 2021; Chandio *et al.*, 2021ab; Woldeselassie *et al.*, 2021). These above stresses may negatively affect cropping patterns, crop yields, and food production, leading to food shortages (Ahmad *et al.*, 2017; FAO, 2019; Islam *et al.*, 2021).

Vietnam is a developing country in Southeast Asia, and most citizens are smallholder farmers who own from 0.4 hectares (ha) to 2.5 ha of farmland on average. In 2020, the rice cultivation area was 7.28 million ha, rice production was at 42.69 million tons, and the export volume of rice was 6.15 million tons (General Statistics Office of Vietnam - GSO, 2021). According to World Bank (2020), the average annual temperature in Vietnam increased by 0.5^{o}C to 0.7^{o}C from 1958 to 2007. On the other hand, rainfall is projected to decrease in the dry season and increase in the rainy season.

Located in the North Central Region, Nghe An province is the largest province in Vietnam with an area of agricultural land of 1.25 million ha, and 83% of Nghe An' s population is dependent on agriculture (Nghe An Portal, 2014; Thai *et al.*, 2019; Nghe An Statistical Office - NASO, 2020; GSO, 2020). In recent years, climate change has declined the yields of most crops, especially rice production (Nghe An's DARD, 2020; Zougmoré *et al.*, 2021). Floods often occur, especially flash floods, landslides are common in mountainous areas, and erosion, high tides, and storms are frequent in the coastal plain. Moreover, heatwaves are another climactic event that occur frequently in this province, leading to drought and crop loss in this area (Le *et al.*, 2011; Vietnam Institute of Meteorology, Hydrology and Environment - IMHEN, 2016; NASO, 2020). . Moreover, farmers are encouraged to adopt climate-resilient crops, such as short-duration rice varieties with submergence tolerance and drought tolerance; plant seedlings of Melia azedarach and Acacia trees; and raise livestock. Weather forecasting and building reasonable irrigation regulation plans are other strategies to improve households' resilience in this province (Yang *et al.*, 2016; Nghe An's DARD, 2020). Many previous studies have focused on the effects of climate change on households' livelihoods and adaptation strategies in Vietnam (Tran *et al.*, 2016; Le *et al.*, 2018; Hoang, 2019; Huynh *et al.*, 2020; Kieu *et al.*, 2020; Lindegaard, 2020); however, similar research for Nghe An province is limited (Tran *et al.*, 2016; Hoang, 2019). In the absence of effective adaptation measures, crop production can be severely constrained by climate change in the province (Williams *et al.*, 2019). This situation calls for effective adaptation practices of agricultural systems to enhance farmers' resilience to the impacts of climate change.

This study investigated climate trends in combination with a survey of the adaptive strategies of farmers toward climate change in Nghe An, and the outcomes are expected to provide proper adaptive strategies to climate change and useful information for regional planning in Nghe An province as well as other similar areas.

Methodology

Study area

In this study, Yen Thanh (25.3 thousand ha), Dien Chau (18.1 thousand ha), and Quynh Luu (14.8 thousand ha), were selected as study sites because they are considered as the top rice-producing areas in Nghe An province (NASO, 2020) (**Figure 1**). Quynh Luu and Dien Chau are two coastal plain districts, while Yen Thanh is adjacent to the above districts. In the rainy season (from May to October), the average monthly temperature is 27°C, although the highest temperature can reach 42°C, and rainfall is about 80% of the total yearly rainfall. In the dry season (from November to April), the average monthly temperature is 19°C and the lowest temperature may fall to nearly 0°C. The average rainfall ranges from 1,200-2,000mm per year (Nghe An Portal, 2014).

Sampling and data collection

For meteorological data collection, the secondary data of average rainfall and temperature from 1995 to 2019 were collected from the metrological data station in Quynh Luu district, then converted into monthly and seasonal forms. Moreover, the seasonal data (winter-spring season and summer-autumn season) on the area and yield of the rice crops in Nghe An province were collected from the website of GSO.

Household surveys were conducted from July to August in 2020 (the first batch) then restarted from April to May in 2021 (the second batch) (the disruption was due to the Covid-19 pandemic). To achieve the targets of this study, respondents in the study sites were the heads of smallholder households whose farm size was equal to or less than 2ha. The authors contacted the local government and village leaders for permission about the content and schedule of the interviews. On the decided dates, face-to-face interviews between interviewers and household heads were performed for 40-60 min to go through all the questions.

The total population of rice producers in the three selected districts was 236,234 (Nghe An's DARD, 2020). The sample size was calculated according to Yamane (1967) with a margin of error of 5% using the formula:

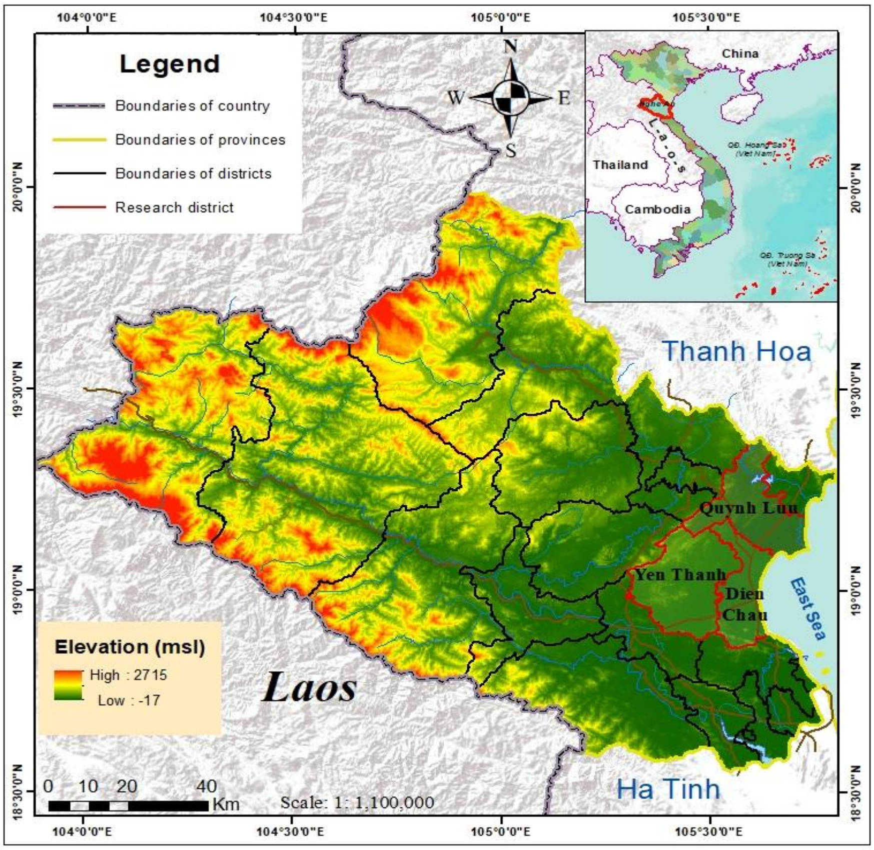

Figure 1. Study Sites: Yen Thanh, Quynh Luu, and Dien Chau districts in Nghe An province

$n = \frac{N}{1+Ne^2} = \frac{236,234}{1+236,234\times(0.05)^2} = 399.3 \approx 400$;

where n indicates the sample size, N indicates the population, and e indicates the margin of error.

As a result, 400 households were surveyed from the three districts, with the values of 171, 91, and 138 for Yen Thanh, Quynh Luu, and Dien Chau districts, respectively. At the field survey stage, a random selection technique was used to identify a total of 396 households, including 151 for Yen Thanh, 122 for Quynh Luu, and 123 for Dien Chau.

Data analysis

Climate change and rice productivity in Nghe An province from 1995 to 2019

Descriptive statistics and several graphs were used to exhibit the trends of temperature, rainfall, and rice productivity in Nghe An from 1995 to 2019. The Mann–Kendall non-parametric test and Sen's slope estimator were used to analyze the trends of the hydrometeorological series and estimate the magnitude of the climatic data (Ahmad *et al.*, 2015; Gadedjisso-Tossou *et al.*, 2021). The null hypothesis was that there was no trend in rainfall and temperature over time, and the alternate hypothesis was that there was an increasing or decreasing trend over time.

Factors affecting households' adaptation strategies in the study area

In this study, several households reported that they used more than one type of adaptation strategy, implying that a household may adopt more than one strategy to deal with the impacts of climate change (Adeleke, 2019; Huynh *et al.*, 2020; Kieu *et al.*, 2020). Therefore, the multivariate probit (MVP) model was employed to analyze the determinants of farmers' choice of adaptation methods. This model allows for correlation among the choices of adaptation strategies after covariates are controlled for (Cappellarri and Jenkins, 2003). The base category referred to those households that did not adopt any strategy. In the study area, there were four major strategies employed for the MVP, namely changing the planting schedule (SCHEDULE), planting stress-tolerant crops (STCROPS), improving irrigation practices (IRRIGATION), and utilizing fertilizers and other good practices (FERTILIZER). In this study, improved irrigation practices included alternate wetting and drying (AWD), system of rice intensification (SRI), and drainage management (Bhusal *et al.*, 2020; Woldeselassie *et al.*, 2021). Besides fertilizer, other good practices included crop covering methods, rice-legume crop integration, mulching, and using farmyard manure (Komba & Muchapondwa, 2018; Williams *et al.*, 2019; Bhusal *et al.*, 2020; Chandio *et al.*, 2021a; 2021b).

The coefficients in the MVP regression are explained as the additional increase or decrease in the log-odds ratio for the dependent variable in response to a unit increase in each independent variable. For numerical variables, the coefficient is explained as an average change in the log-odds ratio for a unit increase of the independent variable, holding covariates unchanged. For dummy variables, it is the average change in log-odds ratio for a change from 0 to 1 in the independent variable, holding covariates unchanged (Cappellarri & Jenkins, 2003). In this study, STATA version 16 was used for data analyses.

Results and Discussion

Climate change and rice productivity in Nghe An province from 1995 to 2019

Figure 2 shows the trends of rainfall and temperature in the winter-spring season in Nghe An province based on historical data from 1995 to 2019. Rainfall fluctuated over the 25 year period and exhibited a significant overall decreasing trend. Controlling for district fixed effects, the results showed that rainfall declined by 0.66 mm per annum on average over 25 years and temperature slightly increased by 0.04^{o}C per annum in the same period. **Figure 3** shows that in the winter-spring season, rainfall rose by 2.29 mm per annum on average over 25 years and temperature increased by 0.05^{o}C per annum in the same period.

Figure 4 shows that the productivity of rice in the winter-spring and summer-autumn seasons rose by 5 tons and 13 tons per annum on average over 25 years, respectively. In this study, only rainfall and temperature were analyzed. However, besides climate change and variability, many other factors also influenced rice productivity, such as improved rice varieties, agricultural mechanization, and new farming techniques. Many farmers strictly implemented the seasonal schedule, in which the summer-autumn crops were grown after harvesting the winter-spring crops to avoid waterlogging, pests, and diseases. In flood-prone areas, planting

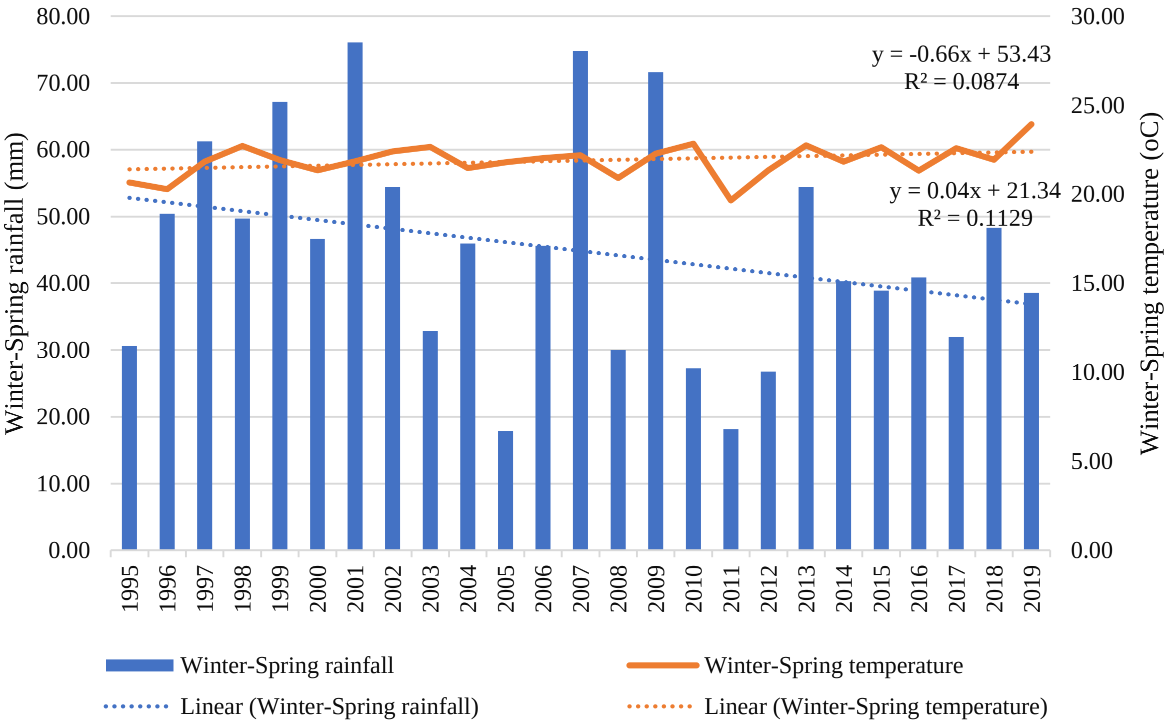

Figure 2. Trends of average rainfall and temperature in the winter-spring season in Nghe An province from 1995 to 2019

Source: GSO (2021).

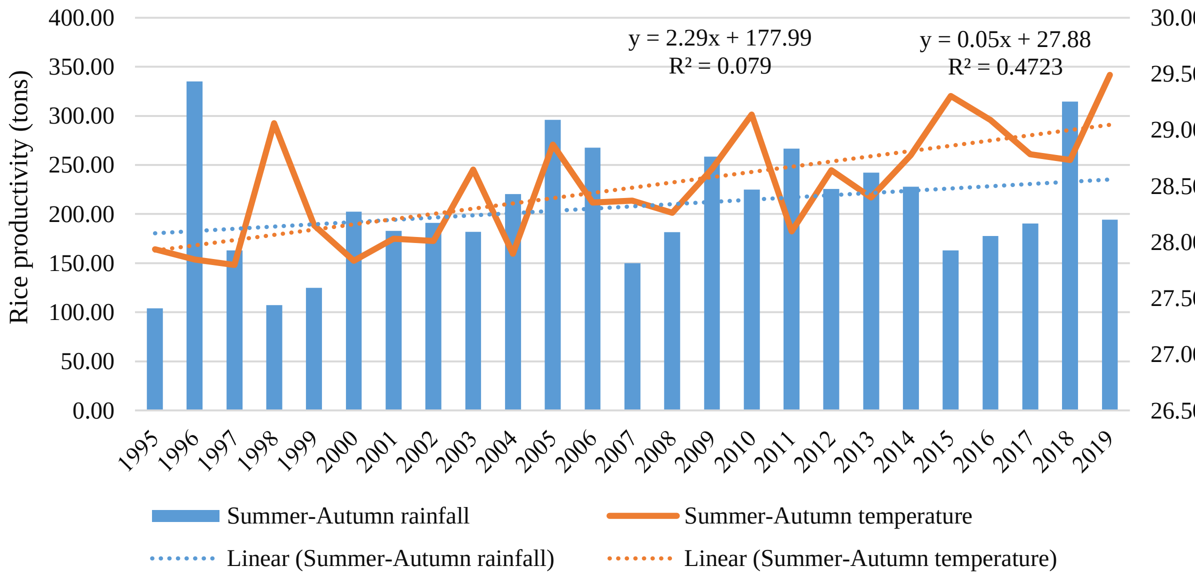

Figure 3. Trends of temperature and rainfall in the summer-autumn season in Nghe An province from 1995 to 2019

Source: GSO (2021).

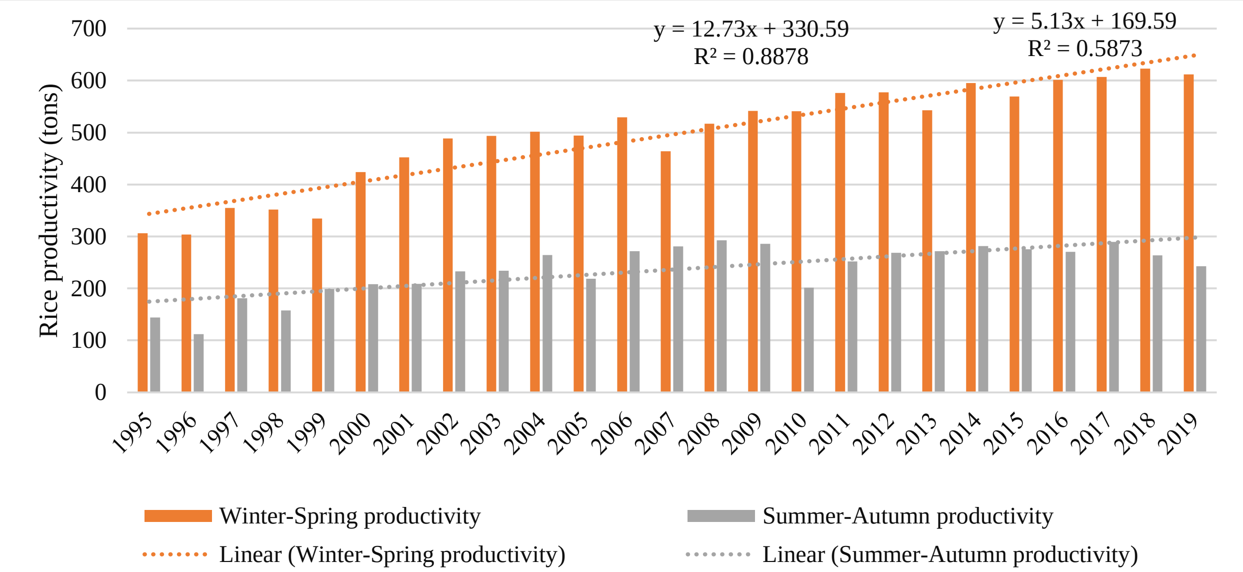

Figure 4. Seasonal trends of rice productivity in Nghe An province from 1995 to 2019

Source: GSO (2021)

short-term varieties (less than 100 days) was encouraged by the local government. Moreover, using machines in transplanting and harvesting rice can reduce labor costs and crop losses compared with the manual methods (Nghe An's DARD, 2020).

Table 1 shows that temperature in the summer-autumn season (28.5°C) was higher than the winter-spring season (22°C) on average. The total area and rice yield in the winter-spring season were higher than in the summer-autumn season because of the availability of water for irrigation and favorable weather conditions for rice cultivation during this season. Because of the lack of irrigation and drainage systems, farmers who grow summer-autumn crops may face risks of water shortage in the late dry season and flooding in the wet season, especially in Yen Thanh and Dien Chau districts (Nghe An's Department of Agriculture and Rural Development - Nghe An's DARD, 2020; GSO, 2021).

In **Table 2**, Sen's Slope test analysis over the 25 years (1995-2019) revealed that annual rainfall had decreased in the winter-spring season in the study area (P <0.05). For both the Mann–Kendall test and Sen's Slope test, annual temperature was found to increase in the summer-autumn season (P <0.01). These findings were corroborated by IMHEN (2016) and World Bank (2020). The abnormal distribution of the rainfall observed in the study area led to dry spells throughout the growing season, which were followed by declines in productivity. This situation induced farmers to adopt several adaptation strategies (Gadedjisso-Tossou *et al.*, 2021).

Socio-demographic characteristics of respondents in the study area

In **Table 3,** the results of the chi-square test and H-test reveal the differences across the three districts in terms of farm size, extension services, access to credit, awareness, temperature, and living in Dien Chau or Quynh Luu. Most of the household heads in the study area were male (79%) and only 11% were female. Approximately 53% and 71% of the respondents belonged to a farmers' organization and a cooperative, respectively. Fifty-nine percent had access to credit, 73% had access to irrigation, only 8% of respondents had access to extension services, and less than 5% of them had awareness about climate change. However, 94% of them reported that they experienced a change in temperature and 78% of them experienced fluctuation in rainfall. This means many rice

Table 1. Climatic factors and yield by growing season in Nghe An province

Variable	Winter-Spring season				Summer-Autumn season			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
Area (thousand ha)	85.51	4.99	72.70	92.40	55.25	5.43	42.30	65.60
Yield	5.76	0.89	3.86	6.75	4.24	0.62	2.65	5.14
Rainfall (mm)	44.82	16.49	17.92	76.08	207.71	59.87	104.13	335.00
Temperature (ºC)	21.89	0.91	19.66	23.94	28.49	0.50	27.80	29.49
No. of observations	25				25			

Source: GSO (2021)

Table 2. Mann–Kendall test and Sen's Slope test for seasonally trend analysis of rainfall and temperature in the study area

Season	First year	Last year	Mann-Kendall test	Sen's Slope test
Rainfall (mm)				
Winter-Spring	1995	2019	-0.22 (0.1231)	-2.07 (0.038)**
Summer-Autumn	1995	2019	0.23 (0.1176)	1.30 (0.195)
Temperature (◦C)				
Winter-Spring	1995	2019	0.22 (0.1349)	1.40 (0.163)
Summer-Autumn	1995	2019	0.52 (0.0003)***	4.60 (0.000)***

*Note. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.*

farmers in the study area suffered due to climate change.

Table 3 shows that the age of the respondents was high on average (more than 54 years old). The number of people of working age was 314 respondents, accounting for 79% of the total respondents. Most of the sampled respondents had formal education with an average of eight years of education, implying that many farmers had a low level of formal education, which affected their capacity to adapt to climate change. The mean farm size was 0.2 ha, and the mean household size was four persons. Farm size and household size were considered as capital and labor inputs for rice-producing, respectively, which affected the farmers' choice of adaptation method. Holding large farms may stimulate farmers to adopt agricultural mechanization, fertilizer technology, and farming techniques to increase output. Since hired laborers often work for a wage and lack incentives to improve productivity, a big household with many laborers has an advantage in rice production (Ngo & Hoang, 2016).

Agricultural adaptation strategies of respondents in the study area

Table 4 shows the main adaptation strategies to climate change of the respondents in Nghe An province. The study results show that about 62% of the farmers did not utilize any adaptive strategies, 12% of the households adopted improved irrigation practices (IRRIGATION), 11% of farmers adopted stress-tolerant crops (STCROPS), 9% adopted changing the planting schedule (SCHEDULE), and 6% applied fertilizer and other good practices (FERTILIZER) to cope with the impacts of climate change. The results of the chi-square test revealed the differences across the three districts in terms of changing the planting schedule due to differences in topography ($P < 0.05$) (Alem *et al.*, 2010).

Due to the impacts of climate change, such as variations in temperature and fluctuations in the rainfall pattern, many smallholder farmers followed the instructions of the local authorities in adopting different strategies to improve their resilience to climate change. They may have changed the planting schedule, modified the

Table 3. Socio-demographic characteristics of the respondents across the three districts

Variables	H-Test								Chi-Square Test						
	Dien Chau		Quynh Luu		Yen Thanh		Total		Dien Chau		Quynh Luu		Yen Thanh		*P*-value
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Age (years)									56.29	11.17	54.41	10.15	55.07	10.74	0.487
Gender (1 for male; 0 otherwise)	95	77.24	99	81.15	120	79.47	314	79.29	0.77	0.42	0.81	0.39	0.79	0.41	0.75
Education (years)									7.93	2.60	8.20	2.63	8.38	2.62	0.585
Farm size (ha)									0.28	0.21	0.23	0.22	0.21	0.13	0.001***
Household size (persons)									4.41	1.84	4.44	1.80	4.06	1.67	0.218
Cooperative (1 for yes, 0 otherwise)	84	68.29	85	69.67	111	73.51	280	70.71	0.68	0.47	0.70	0.46	0.74	0.44	0.612
Farmer organization (1 for yes, 0 otherwise)	62	50.41	65	53.28	83	54.97	210	53.03	0.50	0.50	0.53	0.50	0.55	0.50	0.752
Extension services (1 for yes, 0 otherwise)	16	13.01	14	11.48	3	1.99	33	8.33	0.13	0.34	0.11	0.32	0.02	0.14	0.001***
Access to credit (1 for yes, 0 otherwise)	85	69.11	73	59.84	74	49.01	232	58.59	0.69	0.46	0.60	0.49	0.49	0.50	0.003
Awareness (1 for yes, 0 otherwise)	1	0.81	18	14.75	2	1.32	21	5.30	0.01	0.09	0.15	0.36	0.01	0.11	0.000***
Access to water for irrigation (1 for yes, 0 otherwise)	92	74.80	85	69.67	112	74.17	289	72.98	0.75	0.44	0.70	0.46	0.74	0.44	0.609
Temperature (1 for variability, 0 otherwise)	110	89.43	112	91.80	150	99.34	372	93.94	0.89	0.31	0.92	0.28	0.99	0.08	0.001***
Rainfall (1 for variability, 0 otherwise)	95	77.24	96	78.69	118	78.15	309	78.03	0.77	0.42	0.79	0.41	0.78	0.41	0.962
Dien Chau (1 for Dien Chau district, 0 otherwise)	123	100.00	0	0.00	0	0.00	123	31.06	1.00	0.00	0.00	0.00	0.00	0.00	0.000***
Quynh Luu (1 for Quynh Luu district, 0 otherwise)	0	0.00	122	100.0	0	0.00	122	30.81	0.00	0.00	1.00	0.00	0.00	0.00	0.000***

*Note: P-values are for the chi-square test)binary variables(and H-test)numerical variables(for the differences across the three districts; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively*

Table 4. Major adaptation strategies to climate change of the respondents in the study area

District	Dien Chau		Quynh Luu		Yen Thanh		Total		*P*-value
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	
Changing plant schedule	18	14.63	6	4.92	13	8.61	37	9.34	0.030**
Improved irrigation practices	17	13.82	11	9.02	20	13.25	48	12.12	0.446
Stress-tolerant crops	19	15.45	9	7.38	16	10.60	44	11.11	0.128
Fertilizer and other good practices	8	6.50	3	2.46	11	7.28	22	5.56	0.192
No adoption	61	49.59	93	76.23	91	60.26	245	61.87	
Total	123	100	122	100	151	100	396	100	

*Note: p-values are for the chi-square test)binary variables(for the differences across the three districts; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.*

application of fertilizers and other inputs, applied mulch, practiced shifting cultivation, or used improved varieties, especially in rain-fed areas (Ahmad *et al.*, 2017; Williams *et al.*, 2019). According to Nghe An's DARD (2020), farmers sow seeds for the autumn-winter season sooner than before, right after harvesting winter-spring rice to avoid many floods and storms in the rainy season.

High temperature induced farmers to cultivate drought-resistant varieties to reduce crop loss, and maintain productivity and farm revenues. Temperatures above 32°C harm seed set, pollen availability, and pollen disposition, and lead to a reduction in rice yield (Krishnan *et al.*, 2011; Adeleke, 2019; Chandio *et al.*, 2021b). The use of climate-resilient crops and varieties are practical strategies to reduce the impacts of climate change such as drought, flood, disease, and pests (Bhusal *et al.*, 2020). Farmers in the study areas were familiar with indigenous rice varieties that have outstanding characteristics (i.e. short-term growth, heat-tolerance, and high-quality), such as Khang Dan, NA2, Na6, AC5, TBR 225, BC15, Bac Thom, and Thien Uu 8. These varieties can be grown to avoid extreme rainfalls and floods in July and August. However, their yields are fairly low compared to improved varieties that produce high yield, and have cold tolerance and pest resistance, such as Thai Xuyen 111, VT404, and VT505 (Nghe An' DARD, 2021b).

As irrigation is critical for crop farming, improving a field's water system is a potential method to help plants survive during the crop growth period because newer systems require less water and help farmers minimize yield loss when there are extreme weather conditions (Williams *et al.*, 2019). Many farms surveyed used underground water sources such as wells, boreholes, channels, and rivers for irrigation. In addition, other water-saving technologies for rice were adopted by farmers including drainage management and alternate wetting and drying (AWD). The AWD technique can significantly improve water productivity and decrease the risks of pest and disease damage while increasing grain yield under continuously submerged conditions (Zhuang *et al.*, 2019; Cao *et al.*, 2021). SRI can enhance rice yield while reducing farm work and the cost of rice production (i.e. hiring laborers, buying nitrogen fertilizers and pesticides) (Ngo & Hoang, 2016; Bhusal *et al.*, 2020; Woldeselassie *et al.*, 2021). The application of proper soil nutrition management to improve soil fertility is another option, and includes the provision of fertilizers, mulching, farmyard manure management, and seasonal migration by households (FAO, 2015; Komba & Muchapondwa, 2018; Williams *et al.*, 2019;

Table 5. Factors influencing the adoption of the adaption strategies: MPV

Variable	Changing plant schedule (SCHEDULE)	Stress-tolerant crops (STCROPS)	Improved irrigation practice (IRRIGATION)	Fertilizer and other good practices (FERTILIZER)
Age (years)	-0.013 (0.231)	-0.021** (0.029)	-0.025*** (0.005)	-0.015 (0.242)
Gender (1 for male, 0 otherwise)	0.122 (0.689)	0.094 (0.749)	0.183 (0.531)	0.809* (0.073)
Education (years)	-0.066* (0.096)	-0.051 (0.177)	-0.065* (0.066)	-0.092* (0.061)
Farm size (ha)	0.073 (0.961)	0.075 (0.952)	0.870 (0.708)	11.989*** (0.008)
Farm size squared (ha^2)	-0.351 (0.840)	-0.029 (0.979)	-2.144 (0.611)	-18.837** (0.020)
Household size (persons)	0.064 (0.323)	0.108* (0.065)	0.091 (0.107)	0.107 (0.155)
Cooperative (1 for yes, 0 otherwise)	0.619** (0.042)	0.628** (0.022)	0.422* (0.098)	0.286 (0.397)
Farmer organization (1 for yes, 0 otherwise)	0.380* (0.100)	0.493** (0.018)	0.326* (0.092)	0.183 (0.492)
Extension services (1 for yes, 0 otherwise)	-0.754 (0.196)	-1.099 (0.165)	-1.233* (0.072)	-0.937 (0.225)
Access to credit (1 for yes, 0 otherwise)	-0.289 (0.177)	-0.382* (0.052)	-0.472** (0.019)	0.137 (0.579)
Access to water for irrigation (1 for yes, 0 otherwise)	-0.721*** (0.001)	-1.277*** (0.000)	-1.343*** (0.000)	-0.837*** (0.001)
Temperature (1 for variability, 0 otherwise)	0.052 (0.894)	-0.480 (0.116)	-0.193 (0.552)	3.754 (0.978)
Rainfall (1 for variability, 0 otherwise)	0.251 (0.392)	0.099 (0.732)	0.005 (0.987)	0.938* (0.060)
Awareness (1 for yes, 0 otherwise)	0.361 (0.507)	0.005 (0.992)	-0.086 (0.876)	-2.172 (0.994)
Dienchau (1 for Dien Chau district, 0 otherwise)	0.500** (0.043)	0.168 (0.497)	0.023 (0.922)	-0.155 (0.582)
Quynhluu (1 for Quynh Luu district, 0 otherwise)	-0.215 (0.425)	-0.359 (0.132)	-0.441* (0.051)	-0.706** (0.035)
Constant	-0.993 (0.350)	0.272 (0.775)	0.902 (0.324)	-7.01 (0.960)
ρ_{21}	0.944*** (0.000)			
ρ_{31}	0.890*** (0.000)			
ρ_{41}	0.568*** (0.000)			
ρ_{32}	0.950*** (0.000)			
ρ_{42}	0.584*** (0.000)			
ρ_{43}	0.683*** (0.000)			
n = 396				
Wald χ^2 (64) = 129.32 (p = 0.000)				
Log likelihood = -257.58				
Likelihood ratio test χ^2 (6) = 243.10 (p = 0.000)				
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$				

*Note: The P-values are given in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.*

Bhusal *et al.*, 2020; Chandio *et al.*, 2020; Woldeselassie *et al.*, 2021). In the summer-autumn season, fertilizers can quickly dissolve in water due to hot weather; therefore, reducing the quantity and increasing the frequency of applying fertilizer can limit the loss of fertilizer in fields.

There exist several barriers to implementing the adaptation strategies mentioned above. For example, inconsistent planting schedules were still being implemented despite the unfavorable weather of heavy rain and storms during harvest time (United Nations Industrial Development Organization-UNIDO, 2012). Extreme rainfalls may induce nutrient leaching from the soil. In the study area, many improved varieties were cultivated but some indigenous varieties with long-term growth and a high risk of lodging were still grown due to a lack of information (Nghe An's DARD, 2021b). Other difficulties affecting the adoption of the adaptation strategies were the lack of additional laborers at the commune level, increased costs of agricultural inputs (i.e. seeds, chemicals, and fertilizers), and irrigation facilities that were not designed towards climate-smart agriculture or with water-saving technology (Oxfam America, 2014).

Factors affecting farmers' choice of adaptive capacity to climate change in the study area

Table 5 presents the MVP estimates of the factors influencing the adoption of each adaptation strategy in the study area. The Wald chi-square statistic 129.32 (P <0.01) indicated that the independent variables used for the MVP significantly influenced the dependent variables (i.e. farmers' choices of adaptive strategies). As for inter-strategy correlation of the error terms, positive correlations were found. This indicated that households were more likely to adopt more than one strategy simultaneously, after controlling for the observables.

Age of household head had a negative influence on the adoption of STCROPS and IRRIGATION. An increase in a farmer's age by one year would reduce the farmer's likelihood to adopt stress-tolerant crops and improved irrigation practices by -0.021 and -0.025, respectively. The results implied that older farmers were less likely to be flexible than those who were younger, and thus, they had a lower likelihood of adopting stress-tolerant crops and improved irrigation practices as adaptation strategies. This might be because the elderly faced problems with their health and the reduction of their productivity; therefore, they were less risky than younger farmers, which is in line with previous studies by Alem *et al.* (2010), Adeleke (2019), and Islam *et al.* (2021).

Gender of the household head had a positive significant influence on the adoption of FERTILIZER, indicating that male-headed households were more likely to adopt fertilizer and other good practices than female-headed households. This is consistent with previous research, which found that men may be more positive towards the adoption of higher intensities of fertilizer and any farm practices for increasing yield than women, resulting in gender variances in farm productivity (Alem *et al.*, 2010; Kassie *et al.*, 2017). Other reasons were that most of the household heads in the study area were male (80%), most agricultural activities were performed by the male farmers, and thereby, most of the choices about adaptation strategies were made by male farmers (Islam *et al.*, 2021). Moreover, as this strategy creates more work for women, they were less adaptive to using it compared to male farmers (Alem *et al.*, 2010; IFAD, 2012; Zougmoré *et al.*, 2021).

Education of household head had a negative influence on the adoption of SCHEDULE, IRRIGATION, and FERTILIZER. A one year increase in the number of years of education would reduce the probability of adopting changing the planting schedule, improving irrigation practices, and using fertilizer and other good practices by -0.066, -0.065, and -0.092, respectively. According to previous studies, many farmers practiced different sowing dates and planting diverse varieties with different growth times. In the dry season, water for irrigation from the pumping station was not efficient to meet the requirements for the growth of rice. Other difficulties were related to community awareness about the technical requirements and effectiveness of SRI, and the habit of producing conventional rice cultivation using less farmland to produce rice (Ngo & Hoang, 2016; Hoang *et al.*, 2021). According to UNIDO (2012), poor labor awareness and hurrying while harvesting caused food losses in the field.

Farm size had a non-linear effect on the adoption of FERTILIZER. A one-ha increase in farm size may reduce the likelihood of adopting fertilizer and other good practices by 25.7 points. This may be because of the price of fertilizers for producing rice has been increasing while the price of paddy rice has moved in the opposite direction. As a result, crop yields also decreased, leading to a decrease in rice productivity, especially in the summer-autumn season due to adverse weather. Moreover, households with fragmented farms were less likely to make any changes toward adapting to climate change (Heisse & Morimoto *et al.*, 2019; Nghe An's DARD, 2021a).

Household size had a positive influence on the adoption of STCROPS. An increase in the number of family members by one would increase the likelihood of farmers to cultivate stress-tolerant crops by 10.8% points. Farmers utilized the family laborers for land preparation, weeding, harvesting, and grain processing to cut production costs and meet a shortage of laborers in the agricultural sector (Baruah *et al.*, 2021; Nciizah *et al.*, 2021).

Being a member of a cooperative and/or farmer organization had a positive influence on the adoption of SCHEDULE, STCROPS, and IRRIGATION. This implied the effectiveness of cooperatives and farmer organizations in ensuring farmers' crops and provided farmers access to extension and training, which helped farmers improve farm resilience (Kangogo *et al.*, 2020). The diffusion of information through cooperatives and farmer organizations about climatic events or the occurrences of pests/diseases and their management practices helped farmers actively respond to the impacts of changing climatic conditions, such as changing planting dates, providing supporting aid for irrigation building, and introducing farmers to stress-tolerant crops, which are adapted to harsh climates due to their ability to tolerate heat, salt, and/or water stress (Bhusal *et al.*, 2020; Nciizah *et al.*, 2021).

Extension services had a negative influence on the adoption of IRRIGATION. Extension services reduced the probability of adopting improved irrigation practices by -1.233. This was because the activities from extension services in the study area were not sufficient for practicing climate-smart agriculture. This measure related to actions both on-farm and beyond the farm, and incorporated technologies, policies, institutions, and investments (Ngo & Hoang, 2016; Hoang *et al.*, 2021).

Access to credit had a negative influence on the adoption of STCROPS and IRRIGATION. Households having access to credit would reduce the probability of adopting stress-tolerant crops and improved irrigation practices by -0.382 and -0.472, respectively. Farmers tried to avoid the adoption of any costly strategies due to significant financial investments in improving irrigation systems, especially for small farms in remote areas (IFAD, 2012; Zougmoré *et al.*, 2021). Moreover, farmers may have preferred to use credit to fulfill financial shortages caused by climate shocks and other risks, such as for consumption purposes or other income-generating activities rather than investing in their farms (Alem *et al.*, 2010; IFAD, 2012; Bhusal *et al.*, 2020).

Insufficient access to water for irrigation had a negative influence on the adoption of all four strategies. This result implies that rice production was adversely affected by water constraints in coastal areas due to the low level of the water surface in the dry season. On the other hand, SRI was practiced at a small scale in Nghe An due to the of knowledge of rice farmers on the technical requirements of advanced farming techniques for adaptation to climate change (IFAD, 2012; Ngo & Hoang, 2016; Woldeselassie *et al.*, 2021).

Rainfall had a positive significant influence on the adoption of FERTILIZER. Rainfall variability would increase the likelihood of adopting fertilizer by 0.938 points. Conventional agriculture depends on the application of primary macro-nutrients for increasing rice yield, which includes nitrogen, phosphorus, and potassium

(Buresh *et al.*, 2019). Previous studies have revealed that the high frequency and intensity of extreme rainfall may induce runoff nutrient losses of rice paddy and low nutrient-use efficiency, leading to the need of using more fertilizer to improve soil fertility. This is in line with studies by Wu *et al.* (2020) and Khan *et al.* (2021).

District fixed effects were measured with Yen Thanh being the base category. Households in Dien Chau district were more likely to adopt changing the planting schedule compared to Yen Thanh district. Households in Quynh Luu were less likely to improve irrigation practices and use fertilizer and other good practices to those in Yen Thanh. The differences in the outcome may be due to the availability of water resources for irrigation, topography, location, and the occurrences of weather events (Alem *et al.*, 2010; Rakgase & Norris, 2015).

In general, the average age of farmers has increased over time, and agricultural subsidies for these stakeholders are needed to encourage young people to engage in rice production and ensure the smoothness of activities of the whole supply chain. Given the positive effectiveness of cooperatives and organizations on farmers' adaptive capacities, the diffusion of technology, social learning, and community practices through these channels may be helpful for adaptation strategies in the study areas. Training courses should be provided by extension services to enhance the community's awareness of climate-resilience agriculture. Special farming techniques should be practiced regarding the topography of each district in the study area, especially in Dien Chau and Quynh Luu. Investments to improve the irrigation system in Nghe An province should be the concern of policymakers to cope with water constraints. Next, land consolidation is a potential practice as an adaptation strategy to enhance crop productivity. Lastly, timely weather forecasts could be practiced for enhancing households' resilience to the impacts of climate change.

Conclusions

The results of this study showed a decline in rainfall in the winter-spring season and an increase in the summer-autumn season. Rice productivity increased over time due to advanced agricultural technology and other factors such as irrigation systems and fertilization. More than 60% of the respondents did not utilize any adaptive strategies in this study, but of those who did, the main methods were improving irrigation practices, planting stress-tolerant crops, changing the planting schedule, and using fertilizer and other good practices to cope with the impacts of climate change.

The results of the MVP showed that age, education, extension services, access to credit, access to irrigation, and living in Quynh Luu negatively affected the farmers' choice of adaptation strategies, whereas gender, household size, cooperative, farmer organization, rainfall, and living in Dien Chau positively affected the farmers' choice of adaptation strategies. The farm size exhibited a non-linear effect on the farmers' choice of adopting fertilizer and other good practices.

In this study the results were cautiously interpreted due to the lack of quantitative information in the field survey, which suggests an intention to conduct future research. Moreover, it is vital to explore the livelihood strategies of farmers under the effects of climate change and the determinants of households' adoption strategies. Last but not least, further research should consider the resilience of farmers in other areas that are more vulnerable to climate change such as mountainous areas in Nghe An province.

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