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Impacts of Seasonal Climate Variability on Rice Production in the Central Highlands of Vietnam

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ABSTRACT

This case study was done to determine the impact of seasonal climate variability on rice production in the Nam Dong District, Central Highland of Vietnam. The Ordinary Least Square method was applied to establish the relationships between climatic factors and rice yields in two different growing seasons. The climatic factors are average maximum temperature (*avemaxT*), average minimum temperature (*aveminT*) and average rainfall (*averain*). The rice growing seasons are known as the Winter-Spring (WS) and Summer-Autumn (SA) season. The data of climate factors and rice yield during these two growing seasons were collected from District Meteorological Station and District Statistical Office over 27 years. The data used was from the years 1986 to 2012. A focus group discussion also was held with local rice farmers. The information gathered during this discussion was processed by using the timeline trend, which is a Participatory Rural Approach (PRA) tool. The farmers were invited to share their thoughts, experiences and opinions related to the impact of climate variability on their individual rice production. Moreover, an in-depth interview was conducted with local extension and agricultural officers to discuss the past losses of rice production caused by climate variability that occurred in Nam Dong district.

The results from Ordinary Least Square show that seasonal *averain*, *avemaxT*, and *aveminT* had significant effect on rice yield. While, it was found that the seasonal *averain* factor had a positive relationship with rice yield and that the seasonal *avemaxT* affected adversely on rice yield of the two growing seasons. In addition, rice yield in the SA season did not relate to seasonal *aveminT*. This climate variable had positive impact on WS rice yield at statistical significant level. Moreover, participants in the focus group discussion reported that many climate events were irregular and unpredictable. An example of this is that droughts occurred more frequently, which caused negative impact on rice production. The result of in-depth interview also confirmed that drought, storm, pest and disease were the main cause losses of rice production under climate variability.

The research results provide valuable information to assist local governments in rural socioeconomic development plans to minimize the impacts of adverse climate conditions. Moreover, Meteorological Stations, agricultural and extension units will also benefit from this data to help improve their communication methods when disseminating to the farmers current or accurate climate conditions, climate predictions and climate patterns.

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1. Introduction

Climatic factors are key determinants to crop production processes; solar radiation, rainfall and temperature fluctuations lead to water deficit, flood, changing in soil moisture content, pest and diseases outbreak that constraint crop growth and can account for 15 - 80% of the variation of inter-annual yield resources (Oerke et al., 2012; Gommes et al., 2010; Yoshida and Parao, 1976; Lansigan et al., 2000).

In Vietnam, rice production plays a crucial role in the country economy. Nearly 80% Vietnamese farmers cultivate rice which is a major staple crop of ethnic minorities in the highland areas (Thanh and Singh, 2006). Rice production contributes to income security, alleviate poverty, and strengthen food security for ethnic minorities (Thang et al., 2006). However, Yu et al. (2010) reported that it tends to have strongest rice yield decreased under both dry and wet climate change scenarios in the Central Highland of Vietnam. Moreover, MONRE (2009) also indicated that a decline of rice yield ranging from 4.2% to 12.5% may be observed in all climate change scenarios in Vietnam in 2030s.

In the face of climate change, understanding climatic impacts on rice production is crucial to identifying solutions that will improve current food production and to increase the adaptability of these systems in the future. In Vietnam, particularly in the Central Highlands of Vietnam, studies on the impact of climate variability of rice production have been very minimal. The objective of this paper is to assess the impact of climate variability on rice production. Accordingly, recommendations will be made to help improve the current agricultural production systems in an effective and efficient adaptation to future climate variability.

2. Material and method

The monthly maximum temperature, monthly minimum temperature, and monthly total rainfall data during the 1986 - 2012 period were taken from Thua Thien Hue Hydro-meteorological Station. The information gathered was used to determine the relationship between rice yield and climate parameters. A focus group discussion was conducted involving local rice farmers to understand their opinions, and their experiences with climate variability and its impact on rice production using the Participatory Rural Appraisal (PRA) tools such as time line trend. In-depth interview was held with agricultural extension officers with regard to the impacts of climate variability on rice production.

Since the number of samples of this study was less than 50, therefore the distribution of rice yield of two growing seasons was checked by using Komogorov-Smirnov and Shapiro-Wilk tests in SPSS software, which is shown in Table 1. Since *p*-value in Komogorov-Smirnov and Shapiro-Wilk test was higher than 0.05, the yield of two different seasons followed normal distribution. Therefore, Ordinary Least Squares is suitable for the estimation of coefficient of determinants.

It is clear that the relationship between climate factors and rice yields was not always linear since the increase of rainfall or temperature would be advantageous for rice yield at a limited threshold. Thus, if these factors increase beyond this threshold, it may adversely influence on rice growth (Mahmood et al., 2012). Furthermore, since this study deals with a small number of observations over 27 years, the Ordinary Least Square equation was estimated by taking log both sides.

$$\mathrm{Ln}Y_{s_t} = \beta_0 + \beta_1 \mathrm{Ln}(averain_t) + \beta_2 \mathrm{Ln}(avemaxT_t) + \beta_3 \mathrm{Ln}(aveminT_t) + \varepsilon_t \quad (1)$$

Where, Y_{st} is rice yield (ton/ha) of two growing seasons (WS and SA), $averain_t$ is the average rainfall (mm) by seasons, $avemaxT_t$ is the average maximum temperature (^oC) by seasons, $aveminT_t$ is the average minimum temperature (^oC) by seasons, ε_t is the error term and t is the time (year). The data for WS rice model was observed and recorded for a 6-month period that is from December to May of the following year. Data was used for SA rice model was obtained over 4-months period which was from May to August and was compiled over the entire 27-year period.

3. Results

3.1. The impact of climate factors on two rice yields by using ordinary least square method

The summary statistics of two different rice growing seasons were presented in Table 2 and Table 3. Over the period of 27 years (1986-2012), rice yields varied between the two different growing seasons. Rice yield in WS was higher than SA season. It is clear that the *averain* in this study area was low in two rice growing seasons at lower around 300 mm and the lowest was at 81 mm from 1986 to 2012. In contrasts, the *avemaxT* was high in both seasons along 27 years of the recorded data. While, the *avemaxT* in WS season ranged around 32.8^{o}C to 37.5^{o}C, it was higher in SA rice season ranged from 36.6^{o}C to 38.6^{o}C. In opposite, the minimum temperature was low in WS rice season at 14.8^{o}C to 18.1^{o}C, but it was quite normal in SA season at 21.5^{o}C to 23^{o}C over 27 years. Nevertheless, these descriptive statistics do not provide any evidence of variability in climate that impacted on rice production.

Table 1 Tests of Normality of dependent variables

Variables	Kolmogorov-Smirnov		Shapiro-Wilk	
	Statistic	Sig.	Statistic	Sig.
Yield_WS	0.129	0.200	0.950	0.217
Yield_SA	0.149	0.127	0.896	0.110

Table 2 Descriptive statistic for Winter-Spring rice yield function

Statistics	Minimum	Maximum	Mean	Std. Deviation	Skewness
Yield_WS	1.26	4.80	2.9185	1.03526	0.240
*averain*_WS	81.43	325.62	162.62	61.49674	1.093
*avemaxT*_WS	32.73	37.47	35.0198	1.02074	0.072
*aveminT*_WS	14.82	18.07	16.4401	0.77162	-0.161

Table 3 Descriptive statistic for Summer – Autumn rice yield function

Statistics	Minimum	Maximum	Mean	Std. Deviation	Skewness
Yield_SA	1.01	4.06	2.2322	0.99902	0.519
*averain*_SA	97.600	308.650	18.2376	55.415460	0.568
*avemaxT*_SA	36.550	38.630	37.7544	0.592422	-0.482
*aveminT*_SA	21.475	22.950	22.1046	0.417527	0.078

In order to provide the quantitative justification for climate variability effected on rice yield during different growing seasons. The Ordinary Least Square was applied in order to establish the relationships of climate parameters such as *avemaxT*, *aveminT* and *averain* with rice yield in two growing seasons. The results of rice yield function were shown in Table 4 and Table 5, which have the same climate factors but were taken into account in difference seasons.

The significance of two models was presented by F value that indicated overall regression models were good for the present data. The R-square values shown that the variables consisted in models explained the variation of rice yield over 27 years at 41.7% in WS and 43.9% in SA season. The results, moreover, shown that the values in Dubin-Watson statistic were not too low to show that the regression models did not suffer seriously from the serial correlation. The VIP values implied that there was no multi-collinearity among independent variables. In addition, *p*-values of Breusch – Pagan chi-square values were more than significant level at 1%, so that we accepted the null-hypothesis about heteroscedasticity. It means that both regression models did not suffer from the problem of heteroscedasticity.

Table 4 Estimate of Ordinary Least Square for Winter-Spring rice season

Variable	Coefficients	Std. Error	t-ratio	VIP
Intercept	7.799	9.879	0.789	
Ln(*averain*)	0.409*	0.207	1.977	1.630
Ln(*avemaxT*)	-5.363*	2.805	-1.912	1.900
Ln(*aveminT*)	3.652**	1.474	2.478	1.375
R-square	*0.417*			
Adjust R-square	*0.341*			
F value	*5.493***			
Dubin-Watson test	*1.062*			
Breusch – Pagan chi-square	*2.957*			
p-value of chi-square	*0.3954*			

** Significant at 5% and * significant at 10%

Table 5 Estimate of Ordinary Least Square for Summer-Autumn rice season

Variable	Coefficients	Std. Error	t-ratio	VIP
Intercept	8.224	20.918	0.393	
Ln(*averain*)	0.808***	0.271	2.986	1.354
Ln(*avemaxT*)	-8.886*	5.137	-1.730	1.316
Ln(*aveminT*)	6.647	4.161	1.597	1.241
R-square	*0.439*			
Adjust R-square	*0.366*			
F value	*5.997***			
Dubin-Watson test	*1.283*			
Breusch – Pagan chi-square	*3.741*			
p-value of chi-square	*0.2980*			

*** Significant at 1%, ** significant at 5% and * significant at 10%

The information contained in Tables 4 and 5 shown that *averain* in both seasons were positively impacted on rice yield, in which *averain* in SA season had stronger affect than WS season. The data shows 1% increase in rainfall without change in temperature would increase rice yield in WS and SA by 0.808% and 0.409% respectively. In contrast, *avemaxT* had negative impacts on rice yield. The results implied that when *avemaxT* increased 1% at no change in rainfall, SW rice yield may decrease 5.363% and SA rice yield could decline 8.886%. The impact of *avemaxT* on rice yield in SA season was stronger than WS since May to August are the hottest months in the Central Highland of Vietnam. It determines that the higher temperature was the more adverse impacted on rice yield during SA season. Unlikely, *aveminT* in SW rice growing season had positive relation with rice yield by 3.652% increasing when *aveminT* developed 1%. This was likely due to the fact that the months from December to March were the coldest months. This also was the time of rice sowing, planting, and growth, so that the lower minimum temperature was the weaker in rice growth and development. Moreover, *aveminT* was not statically significant in SA model. It can be explained that SA was hot season, it was positive association with SA rice yield.

3.2. Farmer's experience on impacts of climate variability on rice production

Table 6 shows the results of using the timeline tool (a PRA tool) during farmer focus group discussion to explore the farmer's perception on climate variability and its impacts on rice production in the last 10 years (from 2002 to 2012) based on their experiences in rice production practices.

Table 6 Farmer's experience of climate variability

Climate events	Impact on rice production
Drought occurred more frequently and severely (2003, 2005, 2011, 2012)	- Paddy fields were dry - Streams dried up. - Paddy land was fallowed - Pests and diseases outbreak
Temperature tent to increase + Winter was warmer + Summer was hotter	- Lacking water for rice field - Rice plants were withered
Rain in rice growing season was lesser Rainstorm in WS disappeared	- Lacking water for rice fields - Low yield - Pests and diseases outbreak
Storms and flood happened suddenly and unusually (2006, 2009)	- Lost yield - Landslide.

Participants reported that droughts occurred more frequently and severely in the years as 2003, 2005, 2011 and 2012. Droughts affected rice cultivation, rice production and were responsible for pests and diseases outbreaks. Farmers in the discussion group stated that many rice areas were only cultivated for one season and then had to be fallowed in the following season due to drought occurrences. According to participants, winters were not as cold as it was before and that the summers were getting hotter. These temperature increase contributed to droughts which in turn caused negative impacts or effects on rice production.

Furthermore, farmers stated that that they received less rain during the rice growing seasons. For example, rainstorms and monsoons did not occur in the month of March. These March rainstorms were a major source of water for both rice growth and development. Water shortage also leads to pest (rats) diseases (blast, sheath blight, brown spots, etc.) which directly contributed to low rice yield.

The last event that the farmers discussed on climate variability is abnormal occurrence of storm and flooding, particularly in the year 2006 and 2009. The consequences of these climate-related hazards were yield loss and landslide on rice fields (Table 7).

Table 7 Losses of rice production cause by climate variability over 10 years

Crops	Impacted area (%)			Yield loss (ton)	Remarks
	Drought	Storm	Pest & Disease		
SA 2003	7.23	-	-	86	Complete loss
WS 2005	-	-	8.42	3.3	Yield decreasing
SA 2005	2.10	-	-	31.5	No planting
WS 2006	5.96	-	12.24	51	Yield decreasing
SA 2006	2.58	0.68	-	38.4	Complete loss
SA 2009	-	0.48	27.20	24	Yield decreasing
SA 2010	-	-	39.33	56	Yield decreasing
SA 2012	1.77	-	8.90	127.1	Complete loss
Total				417.3	

Source: District agricultural office, 2013

Table 7 shown damages and losses in rice production in Nam Dong district recorded by district agricultural office from 2002-2013. This information was obtained from in-depth interview with district agricultural officers. It indicated that drought, pests and diseases were the most serious causes to the rice yield loss. Moreover, the losses happened more in the SA rice season than WS rice season. The data also indicated that drought caused many areas to be fallowed in SA rice season.

The information in Table 7 was consistent with what the farmers discussed in the focus group discussion about the impacts of climate variability on rice production. Moreover, the qualitative data in Table 5 and Table 6 would support evidences for the results in quantitative analysis in assessing the impact of climate variability on rice production in Nam Dong District, the Central Highland of Vietnam.

4. Conclusions

The findings of study exposed that average seasonal rainfall and temperature can be considered as explanatory climate parameters for two rice seasons in Nam Dong district, Vietnam. While, rainfall had positive effect on rice yield, the maximum temperature was negative to rice yield in two growing seasons. Whereas, average seasonal minimum temperature was statistically significant and positively related to rice yield in WS, but not significant in SA season. In addition, the information of the group discussion also supported that many changes in climate, especially drought, were identified by farmers of having the most negative impacts on their individual rice production. It is clearly that rice yield and food are connected to climate variability trends. Hence, it is important to invest in mountainous agricultural research and development in order to supply farmers with more drought-tolerant, storm-tolerant crop varieties, and educate those farmers with efficient production practices which are effective and resilient in various climate conditions. Moreover, the consideration of enhancing or perfecting techniques needed to improve the seasonal climate forecasts while simultaneously disseminating current climate conditions and predictions are a needed requirements to help sustain, improve and increase the agricultural development in the Central Highlands.

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