CHAPTER 5

The Impact of Climate Variability on Rice Production

Due to the geographical characteristics, topography, climate and hydrology mentioned earlier, Thua Thien Hue is one of the provinces most heavily affected by climate variability. According to the report of the Hydro-Meteorology Forecast Center of Thua Thien Hue province, the climatic changes in Thua Thien Hue are also observed in temperature, as well as in the frequency and intensity of climate hazards such as floods, heavy rainfall, droughts, and storms. The studies of Suu et al. (2010) indicated that the annual average temperature in Nam Dong district increased during 1973 – 1982 by 0.6ºC. The rainfall also decreased in summer-autumn season and strong and extreme storms happened more frequently. Many studies reported that higher temperature and its fluctuation could increase the growth rate of pests and diseases, which would make crop more vulnerable (Cruz et al., 2007). Therefore, this chapter aims to present the change in rice yield and the variability of climate factors (maximum temperature, minimum temperature and rainfall) in Nam Dong district in period from 1986 to 2012. Moreover, the impact of climate variability on rice production was illustrated by both quantitative and qualitative data. While, the results of ordinary least square between rice yield and climate factors (maximum temperature, minimum temperature and rainfall) explains for quantitative information. The information that was obtained from focus group discussion about farmer's experience on climate change and its impact on rice production demonstrates for the quantitative data.

5.1 The Rice Yield Change and the Variability of Climate Factors

5.1.1 Rice Yield Change by Seasons

Figure 5.1 shows the changes in the average rice yield of two seasons in Nam Dong District over the last 27 years. It reveals that there was a fluctuation of the rice yield in both winter-spring (WS) and summer-autumn (SA) seasons, especially, the fluctuation increased drastically since 1992. In addition, a slightly increasing trend can be observed over this period, in both seasons. Rice yield in WS season was almost higher than in the SA season except for some years (2005 to 2008 and 2011). The WS yield varied from 1.26 ton/ha (1987) to 4.08 ha (2008) while the SA rice yield was from 1.01 ton/ha (1993) to 4.06 ton/ha (2004). Moreover, for the years that the rice yield dropped, the yield of SA season tended to drop much more than the WS season.

It is noticeable that the SA rice yield had sharp fluctuations among years, especially from 1993 to 2012 of the stage. The highest point was reached in 2004 at 4.06 ton/ha, while there were three times, SU rice yield felt down to the bottom at around 1 ton/ha at 1993, 2003 and 2012.

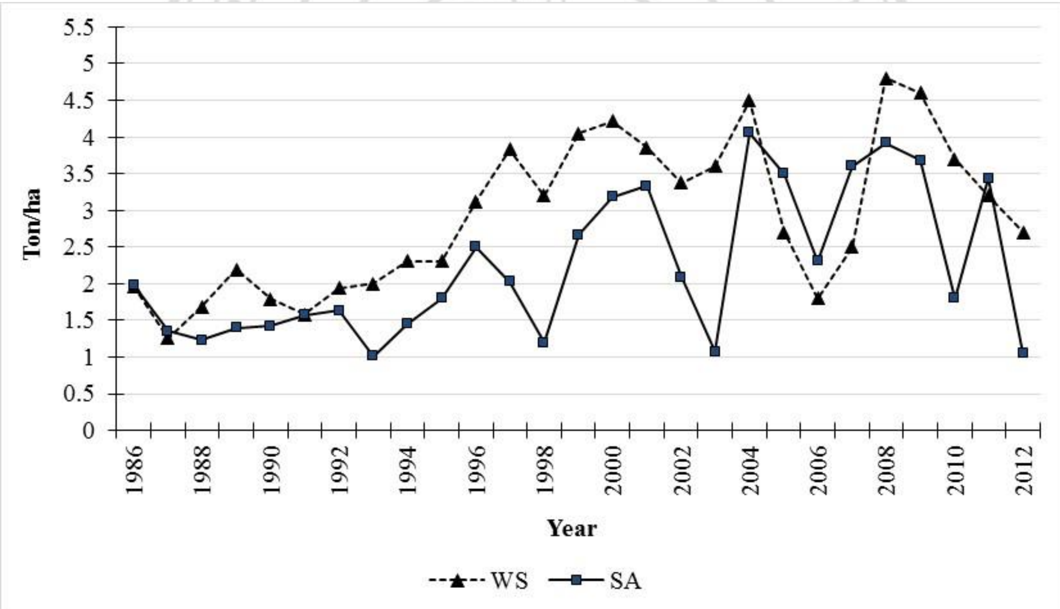

Figure 5.1 Paddy rice yield change over 27 years in Nam Dong

Source: District Statistical Office, 2013

Note: *WS: winter-spring season; SA: summer-autumn season*

The increasing and fluctuating trend of rice yield over years might be attributed to introduction of new rice varieties, technologies and extreme climate factors such as drought, storm, and temperature, heavy rainfall, etc. The following section focuses on the variability of climate factors such as seasonal maximum temperature, minimum temperature, and rainfall would explain for the variability in rice yield.

5.1.2 The Seasonal Temperature Variability by seasons

The distribution of climate factors including maximum and minimum temperatures by two rice seasons is showed in Figure 5.2 and Figure 5.3.

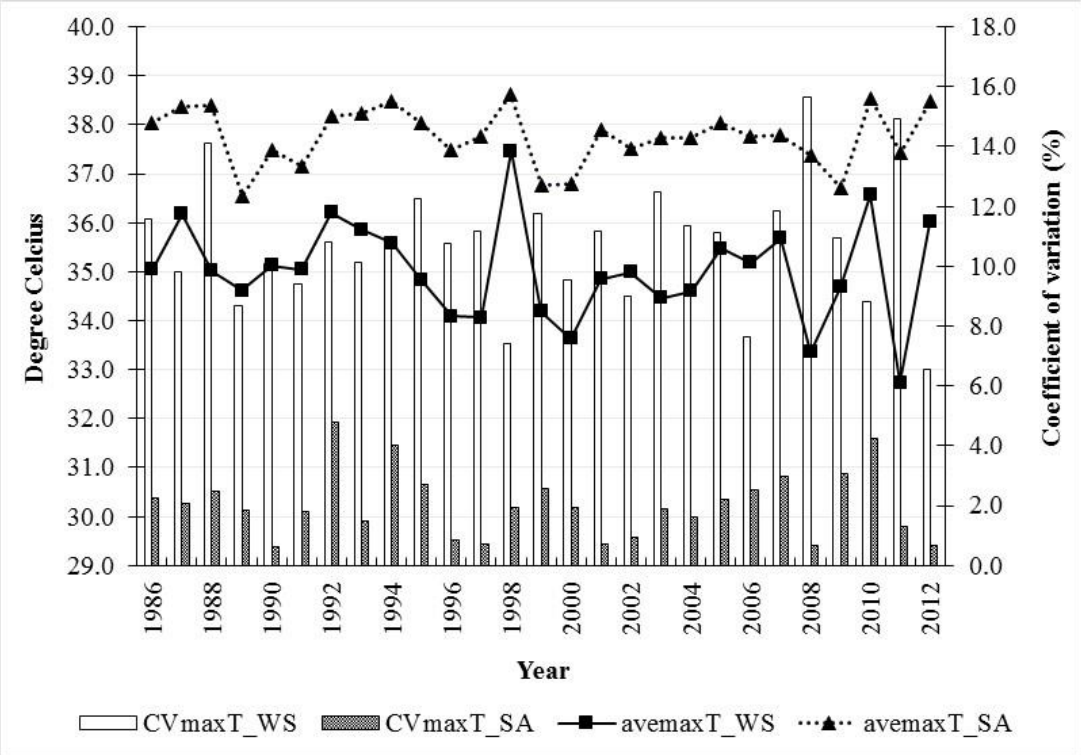

Figure 5.2 The variability of maximum temperature and its CVs over 27 years

Source: Provincial hydro-meteorological office, 2013

Note: *avemaxT: Average maximum temperature*

CVavemaxT: Coefficient variation of average maximum temperature

The Figure 5.2 shows that the average of maximum temperature (avemaxT) of both seasons in Nam Dong district was high and fluctuated strongly over the past 27 years. In WS season, the avemaxT ranged from 32.7°C to 37.5°C, while it was from 36.6°C to 38.6°C for the SA season. Moreover, the distribution of avemaxT during both seasons reached its peak in the year 1998 and kept high numbers in year 2010 and 2012. However, the lowest value of avemaxT_WS and avemaxT_SA were recorded at 32.7°C in 2011 and at 36.6°C in 1989 respectively.

The fluctuation of maximum temperature was analyzed using the value of coefficient variance (CV) as shown in Figure 5.2. Among seasons, WS temperature showed a strong fluctuation with CV ranging from 6.5% to 15.6%, while the fluctuation of SA temperature was slightly lower with CV ranging from 0.4% to 4.8%. In addition, the later years of period, the CV of temperature of two seasons were sharply down. This means that the maximum temperature fluctuation was high in these years. Meanwhile, in WS season, the lowest CV (6.5%) was matched with highest temperature (37.5^{o}C) in 1998, but the highest CV (15.6%) was found with second lowest temperature (33.4^{o}C) in 2008. In contrast, avemaxT had slightly increasing trend in CV in last ten years of this period, especially in 2010.

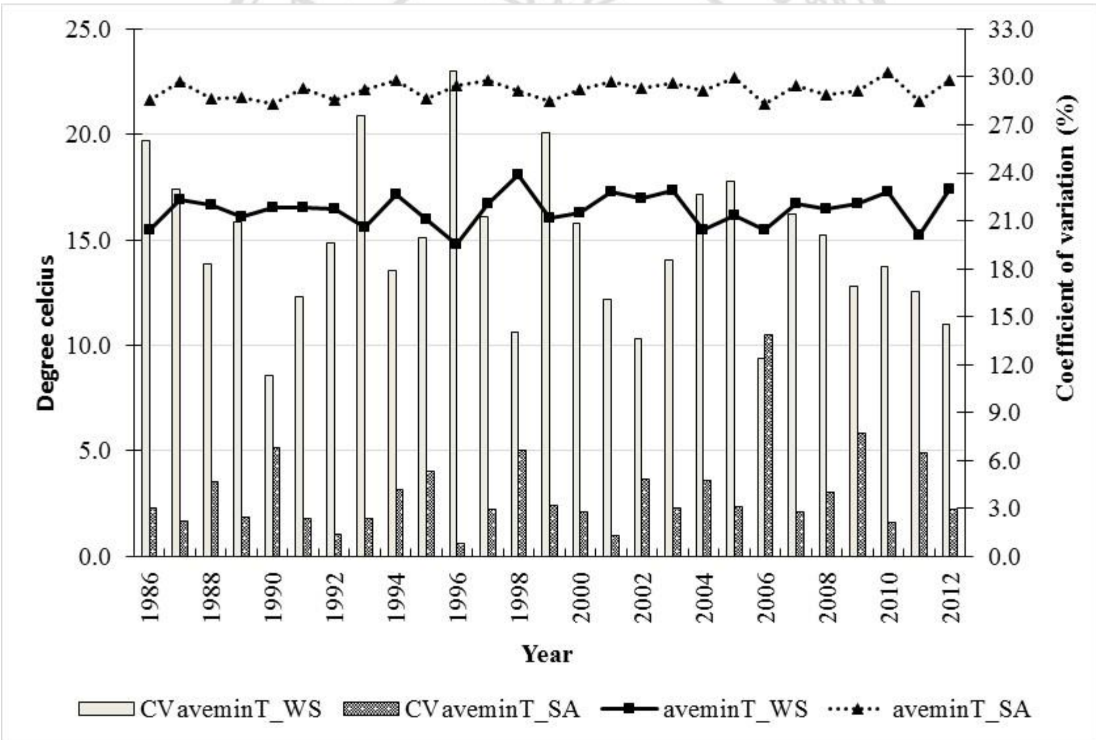

Figure 5.3 The variability of minimum temperature and its CVs over 27 years

Source: Provincial Hydro-Meteorological Office, 2013

Note: *aveminT: Average minimum temperature*

CVaveminT: Coefficient variation of minimum temperature

In contrast with the maximum temperature, the distribution of average minimum temperature (aveminT) and its CV by seasons was different and showed slightly increasing trend, which is shown in Figure 5.3. It is clear that the fluctuation of aveminT in two seasons was not too large. In addition, Figure 5.3 shows that the minimum value of

WS season reached the highest points in the same years of highest values of maximum temperature in 1998, 2010 and 2012 at 18.1^{o}C, 17.3^{o}C, and 17.4^{o}C respectively, but the lowest figure occurred in 1996 at 14.8^{o}C. Nevertheless, the values in SA season were not much different, in which the highest and the lowest points were in 2010 and in 2006 at 23^{o}C and 21.5^{o}C respectively.

Figure 5.3 also presents the fluctuation of minimum temperature in WS was higher than in SA because CVaveminT_WS ranked from 11.3% to 30.4%, but CVminT_SA was 0.8% to 13.9%. It means that minimum temperature among seasons had strongly fluctuation along period. The highest number of CVaveminT_WS happened in year 1996 which was found at the lowest temperature value and this point also was matched with the lowest CVminT_SA. In opposite, the highest figure of CVaveminT_SA was found with second lowest value of aveminT_WS in 2006.

5.1.3 The Seasonal Rainfall Variability by seasons

Nam Dong district is one of the provinces having the largest amount of rainfall in Vietnam with the annual average rainfall ranging from 800 to 1500 mm. The rainy season starts from September to December and a low rainfall period is from February to July which covers two seasons of rice. The drying trend might interrupt the growing seasons of rice that causes rice yield reduction.

The distributions of average rainfall between two rice seasons were presented in Figure 5.4. In spite of strong fluctuations of average rainfall in two rice seasons, but they had decreasing trends throughout the observed period, in which the rainfall values in SA season were higher than WS season excluding some years over the period between 1993 to 2000. The Figure 5.4 indicates that there was a sudden rise in average rainfalls of 1999 and 2000 in both WS (325 mm) and SA (308.7 mm) and then continued fluctuating under 250 mm until the end of the observed period. However, in 1992 the lowest amount of averain_WS at 81.4 mm was observed while averain_SA felt to bottom around 97.6mm in 2012.

The fluctuation of the annual rainfall was also expressed by the coefficient of variation (CV) in Figure 5.4. It points out that there was a strong fluctuation in the average rainfall in two rice seasons, but CVrain_SA was always higher than CVrain_WS in the whole period. The CVrain_SA ranked from 7.8% to 97.4%, but it was only from 7.2% to 55.4% for CVrain_WS. In other words, the highest CV value in WS was almost equal to the lowest CV value in SA. In addition, the highest CVrain_WS value took place in 1999 which was matched with the second highest point of average rainfall, while the lowest figure coincided with the lowest amount of rainfall in the whole period. However, SA experienced the high CVs of rainfall in the years of 1997, 1994, 2001 and 2006 at more than 80%, 86.5%, 89.6%, 82% and 97.4%, respectively. The low CV numbers were recorded in the years of 1997, 1998, 2011 and 2012 at around 20%, whereas other years were above 30%.

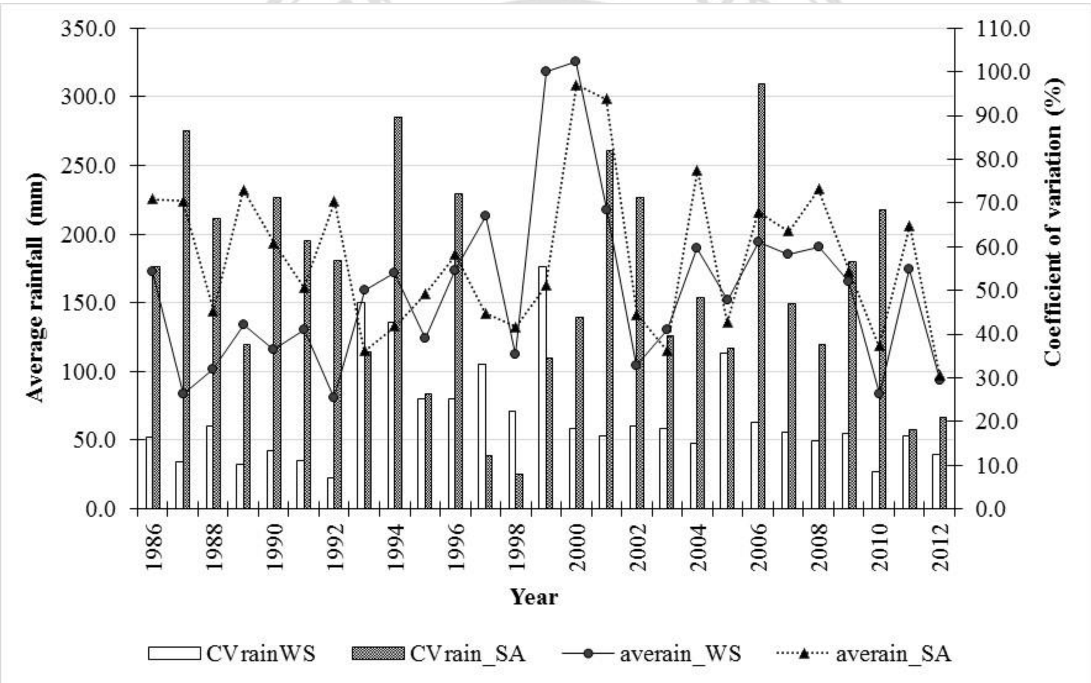

Figure 5.4 The variability of rainfall by seasons and its CVs over 27 years

Source: Provincial hydro-meteorological office, 2013

Note: *averain: Average rainfall*

CVrain: Coefficient variation of average rainfall

The above observation data that presented in Figure 5.2 to 5.4 supports the existence of climate variability in Nam Dong district, Thua Thien Hue province in last 27 years. From the distribution of rice yield and climate factors in two seasons, it can be concluded that there was a relation between rice yield and climate factors. The drops of rice yield in both seasons in some years coincided with the low rainfall and higher temperature. For instance, the lowest rice yield in SA in 2012 happened at the same time of lowest averain (96.7 mm) and highest avemaxT (38.5^{o}C) and high aveminT at 22.6^{o}C in this season. However, these descriptive statistics do not provide any evidence of variability in climate would impact on rice production. Therefore, the quantitative relationship between rice yield and three observed climate factors by season will be discussed in next section by using of regression model.

5.2 Regression Analysis of Impact of Climate Factors on Rice Yield

This section aims to find out the relationship of climate variables such as maximum temperature, minimum temperature and rainfall with rice yield in two seasons (WS and SA) by quantification method. Since the number of samples in this study was less than 50, so the distribution of rice yield of WS and SA season was checked by using Komogorov-Smirnov and Shapiro-Wilk test in SPSS software. The results are shown in Table 5.1. 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.

Table 5.1 Tests of normality of rice yield (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	0.11

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

The results of ordinary least square were shown in Table 5.2 and 5.3 which the same climate factors were taken into account in difference seasons. While the data in Table 5.2 was observed in the period of 6 months from December to next May over 27 years that illustrated the WS rice season model, Table 5.3 used the data of 4 months from May to August to represent for SA rice season model.

Based on the results from regression analysis, the relationship of climate factors and rice yield in two seasons can be written as follows.

+ WS rice season model:

$$\text{Ln yield} = 7.799 + 0.409\text{Ln(averain)} - 5.363\text{Ln(avemaxT)} + 3.652\text{Ln(aveminT)} \quad (4)$$

+ SA rice season model:

$$\text{Ln yield} = 8.224 + 0.808\text{Ln(averain)} - 8.886\text{Ln(avemaxT)} \quad (5)$$

The significant of two models presented by F values that indicates overall regression models were good for the present data at 5% statistical significant level. The R-square values show that the variable consisted in models explained the variation of rice yield over 27 years at 41.7% in WS and 43.9% in SA season. Moreover, the values in Dubin-Watson statistics for serial correlation in two models were not quite good, but these numbers are more than 1, so they can accept that indicates the regression models have positive serial correlation. The VIP values imply that there was no multi-collinearity among independent variables. Furthermore, p-values of Breusch – Pagan chi-square was more than significant level at 1%, so that the null-hypothesis about heteroscedasticity is accepted. It means that two rice regression models did not suffer from the problem of heteroscedasticity.

The results of Table 5.2 show that climate variability explained 41.7% the variation in WS rice yield. P values indicate that averain, avemaxT and aveminT associated with WS rice yield at significant level. Both averain and avemaxT are statistical significant at 10% level, in which 1% increasing in averain without change in temperature would increase rice yield in WS by 0.409%. However, if avemaxT increased 1% at no change in rainfall, WS rice yield might decrease 5.363%. While, aveminT in WS had a positive relation with rice yield, meaning that the rice yield would increase by 3.652% when aveminT rises 5% significant level.

In the SA, the coefficients of variables of rainfall and average maximum temperature in Table 5.3 were statically significant at considerable explanatory power for rice yield model. While, the coefficient of aveminT was not statistical significant in SA model. R^2 value in Table 5.3 means that averain and avemaxT explained 43.9% variation in SA rice yield. The relationship between averain and SA rice yield is positive at 1% significant level. It means that rice yield would increase 0.808% if averain increase 1% without change in temperature. In contrast, maximum temperature had negative relationship with rice yield at 10% statistical significant level. The results implied that when avemaxT increased 1% at no change in rainfall, SA rice yield could decline 8.886%.

Table 5.2 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%

The information in Table 5.2 and Table 5.3 shows that averain in both seasons were positive impacts on rice yield, in which averain in SA season had stronger impacts on rice yield than WS season. While, avemaxT in both seasons had negative relationship with rice yield. The impact of avemaxT on rice yield in SA season was stronger than WS since from May to August were the hottest months in central highland of Vietnam. Hence, the higher temperature was, more adverse the impact on rice yield was in SA season. Moreover, aveminT in WS season just only had a positive relationship with rice yield, but it did not relate to rice yield in SA season. This was likely because the months from December to March were the coldest months. It also was the time of rice sowing, planting, and growth. Thus, the lower minimum temperature was, the weaker rice growth and development was.

Moreover, though the average growing season aveminT was not statically significant in SA model because of dry and hot season, it was positive association with SA rice yield.

Table 5.3 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%

It can be concluded that the seasonal average rainfall, average temperature of maximum and minimum in different seasons had significant effects on rice yield. While, seasonal rainfall factor was found to be in a positive relationship with rice yield, the seasonal maximum temperature adversely impacted on rice yield. However, rice yield in SA did not relate to seasonal minimum temperature, but this climate variable had advantageous impacts on WS rice yield at statistically significant level.

5.3 Qualitative Analysis of Impact of Climate Factors on Rice Production

5.3.1 Farmer's Experience of Climate Variability

A focus group discussion was conducted with 15 rice farmers in order to understand the perception of farmers on climate variability and how these changes affects rice production in the last 10 years from 2002 to 2012. To meet these objectives, the historical timeline was used in the focus group discussion. Firstly the participants were asked to mention the important events occurred in the past that were commonly perceived among local people. These events included weather events as well as other relevant phenomena, were arranged in the timeline. Such a mentioned event with exact known date was used to verify and adjust the others' dates on the timeline. The historical timeline helped participants to recall the key weather events that happened in the past and to correlate them to the changes and impacts in rice production. The results are shown in Table 5.4.

Table 5.4 Weather events over the last ten years

Year	**Key weather events**	**Event description**
2002	*Many rain-storms*	- Rainstorm came many times in March and April but became lesser in later years. - Disease outbreak - Low yield
2003	- *The severe drought* - *Many floods occurred*	- Dry spells from April to August with scorching sunshine. - Water shortage for paddy field, rice yield lost - Streams dried up. - No cold weather in winter season - Cassava field lost yield due to the shortage of water in November and December
2005	- *Severe drought* - *Hails occurred on Mar*	- Stream dried up in SA - Rice, maize, soil bean lost yield.
2006	- *Drought occurred in WS.* - *Prolonged rain in the whole rainy season* - *The super storm occurred*	- Rain occurred with fog - Outbreak of diseases - Storm names Sangsane– the SIXTH storm - Storm happened suddenly - Landslide and stream/river bank erosion. - Houses were damaged. - Rubber trees fell down.

Source: Farmer focus group, 2012

Table 5.4 Weather events over the last ten years (Continue)

Year	**Key weather events**	**Event description**
2009	- *Strong storm* - *Strong flood*	- Storm named NINETH - Landslides in paddy field. - Rubber trees broke down 30%. - Cassava and banana damaged by storm.
2010	*Many rain-storm and hails*	- Appear after 9 years. - Occurred earlier on February - Causes of rice leaf folder, blast disease, and decreased rice yield.
2011	*Mild drought*	- No water for rice - Outbreak of brown spot disease - Rats outbreak
2012	*The severer Drought*	- Drought lasted long, until Sep - There was less rain, flood in the whole year. - Delay of the SA rice season - Paddy areas was left fallow - Weed infestation and rat outbreak

Source: Farmer focus group, 2012

According to the participants, despite the fact that the weather in early 2002 was quite good as there was no drought or any extreme events to occur, some unusual weather phenomena happened, which influenced on rice cultivation. Farmers reported that rainstorms normally occurred during March and April in WS season which provided a good source of water and nitrate for paddy fields, but in 2002, the number of rainstorms increased suddenly and extraordinarily which led to fast growth of rice. However, by farmers' experience, this rapid growth was not a good sign because it made the rice more susceptible to diseases such as rotten trunks, blast, sheath blight, and brown spot. As a result, the yield of WS crop in 2002 was lower compared with previous year (farmer in-depth interview, 2013). Moreover, after 2002, rainstorms in WS season almost disappeared, this was abnormal weather phenomenon that farmer perceived in their district based on their observation experience.

While, farmers did not show any special weather events in 2004, drought occurred again in SA season in 2005 but it was less severe than in 2003. However, many hails that occurred in this year were considered an unusual event in this mountainous area because it had disappeared long time before, the local people reported.

In opposite with the year 2005, drought occurred at the beginning of the year 2006 and rain lasted the months in the end of year. Fogs occurred sometimes during the rainy season, which created a good environment for diseases to develop and attack the WS crops of many farmers. This caused significant loss of rice yield, which has only 1.8 ton/ha in WS season. Moreover, 2006 was also a year with poor harvests for rice farmers due to a super storm named Sangsane that caused soil erosions and landslides resulting in damages and loss on rice crop. Additionally, a large number of rubber trees were also broken down causing a significant loss of income of farmers.

During the focus group discussion, the participants also discussed about the second strong storm that occurred in 2009. The Ninth storm came and lasted for almost 4 days causing waterlogging and flooding as well as landslides. Many crops such as cassava, banana, and particularly rubber trees were significantly damaged by this storm. It was, however fortunate that SA rice was harvested just before the storm arrived, except for some households who lost yield due to late harvesting. Moreover, paddy fields and the local irrigation system were damaged seriously.

The unusual occurrence of hail and rainstorms in 2010 was the events that the participants were concerned as the climate variability. They explained that since the hail took place in February when it was still a cold month in this area, this phenomenon was believed as a manifestation of climate change. Besides, farmers also pointed an abnormal weather in this year that many rainstorms arrived early in February instead of March. Accordingly, the rainstorms created greater conditions for diseases and the development of leaf folder and blast disease that caused the decrease in WS rice yield for year.

The focus group discussion also focused on the drought occurrences in 2011 and 2012, while it was not too server in 2011. Farmers did recall that it was the lack of water caused rice not to flower in SA season in 2011. Therefore, rice brown spot disease and rat outbreak were numerous in this year. Farmers recognized that the year 2012 as a year of a very severe drought with very little rainfall throughout the year. The drought lasted until to September which normally was a rainy month in Nam Dong district. Consequently, it caused a lack of water for irrigation in both rice seasons, especially at the time of rice blooming phase, which is influenced by the pollination rate in SW season. In fact, SA rice crop had to start later due to water stress and some areas were unable to be cultivated because of the cropped land being located at higher altitude and far from water sources. Similarly, the outbreak of weeds and rats occurred causing rice yield decline in both two seasons in this year.

In conclusion, farmers believed that the many weather events in the past 10 years were irregular and unpredictable, particularly droughts that tended to occur more frequently. In addition, many phenomena such as hot weather at the end of year, hail in the beginning of the year, droughts in September, etc. did not fit with the climate pattern as local experiences. Most of the participants thought that it was a need for reliable forecasting systems for them to cope with these kinds of climate variability.

5.3.2 Losses of Rice Production Caused by Climate Variability

As the results of in-depth interviews with district agricultural officers, Nam Dong is located in tropical climate zone. Therefore, it is influenced by hot and the humid tropical monsoons, plentiful sunshine and high temperatures. Since Nam Dong is also the transitional area between the two climates of the northern and southern regions, it has cold winter as the climate of the northern region and hot summer as the climate of the southern region. Nam Dong was also influenced by the air currents coming from various pressure center and has many different types of natural disasters such as hurricanes, tornados, flash floods, droughts, hot dry winds, cold, etc. Every year natural disasters had certain influences on agricultural production, which rice production was one of the most affected.

Table 5.5 shows damages and losses in rice production in Nam Dong district from 2002-2012. The results in Table 5.5 were recorded and updated by district agricultural office yearly. It indicates that drought, storms, pests and diseases were three causes of rice damage and loss and that disease was the most serious cause. Moreover, the losses happened more in SA season than in WS season.

Regarding the impacts of droughts, the largest rice yield loss was in SA season in 2012 with 127.1 ton lost. This was partly because 1.77% of total area was unable to be cultivated due to lack of water, and 8.9% of total area affected by pests and disease infection. In addition, in 2006 there was also a recorded of loss in rice yield due to the drought in SA season. For the impacts of storms, SA season of 2006 and 2009 experienced two strong storms that affected on rice cultivation at 0.68 ha and 0.48 ha correspondingly causing a complete loss.

Table 5.5 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

Pest and disease infection caused the largest damage on rice area in the SA season in 2010 with 39.33% of the rice land affected causing a loss of 56 tons of rice yield. Moreover, the SA season in 2009 was the second largest loss of rice yield in the last 10 years with 27.2% of the area affected by pests and disease outbreaks. These losses and damages were explained in that climatic changes is unpredictable, especially droughts, which caused poor rice growth that lead to poor resistance of rice to pests and diseases.

The information in Table 5.5 is consistent with what farmers discussed in the focus group discussions about the farmers' experience in climate variability and its impacts on rice production. Moreover, the qualitative data in Table 5.4 and Table 5.5 would support evidence for quantitative results in two rice regression models about assessing the impacts of climate variability on rice production in Nam Dong district, the central highland of Vietnam.