# Chapter 24
# The Impact of Weather Variability on Rice and Aquaculture Production in the Mekong Delta

**Dang Kieu Nhan, Nguyen Hieu Trung and Nguyen Van Sanh**

**Abstract** Understanding the impact of weather variability on current agricultural production systems is of great importance for the development of strategies for adapting to and mitigating the potential impact of climate change on food security in the Mekong Delta of Vietnam. This essay assesses the impact of short-term weather variability on rice and aquaculture production, documents ways in which farmers have dealt with weather anomalies, and suggests strategies to adapt to weather and climate variability in the future. Statistical series data (1990–2008) and information collected from previous projects were analyzed. The probabilities of occurrences of weather anomalies were calculated and multiple regression analyses were conducted to identify and estimate significant effects of various weather variables on yields of rice and fish or shrimp in both irrigated and coastal regions. The results showed that temperature and rainfall were the key weather variables that strongly influenced rice and shrimp production. Vulnerability levels to weather variability differed by crops, crop-development stages, cropping seasons, and regions. Rice production was found to be more sensitive to weather variability than was aquaculture, and shrimp production was more sensitive than was *Pangasius* catfish culture. The impacts became more severe during the early vegetative, flowering, and ripening stages of rice crops. The wet-season rice crop and the coastal region were more vulnerable to weather anomalies than the dry-season rice crop and the irrigated region, respectively. Local farmers have coped with temperature and rainfall anomalies in the past by applying appropriate farming techniques. Nonetheless, further measures for adapting to weather and climate variability are essential.

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## 24.1 Introduction

In the Mekong Delta of Vietnam, agricultural production and people's livelihoods are highly susceptible to abnormal events in the Mekong River's flow and in the weather and/or climate. The delta is a low-lying region, where the livelihoods of about 13 million people, 70% of the total population of the area, mainly rely on agriculture and natural-resources exploitation. Hydrological conditions and soil characteristics, which are strongly linked, determine agricultural land uses in the delta (Nhan et al. 2007). The delta is prone to monsoon flooding in the upper delta in the wet season and to salinity intrusion in downstream parts in the dry season. Recent studies have suggested that climate change and sea-level rise would have strong negative impacts on agricultural production and households in the delta (Wassmann et al. 2004; Carew-Reid 2007; ADB 2009; MONRE 2009). Recognizing this challenge, the Vietnamese Prime Minister in 2008 approved the national target program that specifies three stages for coping with climate change up to 2015 (MONRE 2008). The program has been in effect for 2 years. However, the aspect of "adaptation to climate change" still seems to be at an early stage, and practical guidelines for the implementation of adaptation measures are also scarce (Heine 2009).

Rice culture and aquaculture are the principal farming activities of the agricultural sector in the delta. In 2008, around 1.8 million hectares of land in the delta were devoted to rice production and 0.8 million hectares of land were used for aquaculture. The delta accounted for 55% of the total amount of rice and 72% of total aquacultural production in Vietnam (GSO 2010). In the period 2000–2008, the amount of rice-land cultivated in the delta declined by an average of 1% annually, while the average annual growth rate of rice output in the region was 3%. The corresponding figures for the annual aquaculture growth rate were 10% and 23%, respectively (GSO 2010). The main reason for the decline in the land area devoted to rice in the delta is that farmers converted rice land into shrimp farms in coastal areas during the 2000–2008 period. The fact that rice production grew despite the fall in the amount of land in cultivation and the fact that aquacultural output grew more rapidly than the amount of land devoted to aquaculture suggests a trend toward greater intensity in these farming sectors. Coastal shrimp and freshwater *Pangasius* culture are the main drivers of development in aquaculture.

In order to address issues relating to global climate change and food insecurity, the Vietnamese government in 2009 issued a national strategic plan for agricultural land use and food security to 2020. In this plan, the Mekong Delta is recognized as playing a crucial role in national food security. Therefore, understanding the effects of weather variability and the potential impact of climate change on rice and aquaculture systems in the delta is important for developing strategies for adapting to climate change in the future.

The agronomic literature dealing with climatic effects on agricultural production is large and has a long history (Rosenberg 2010). According to data from

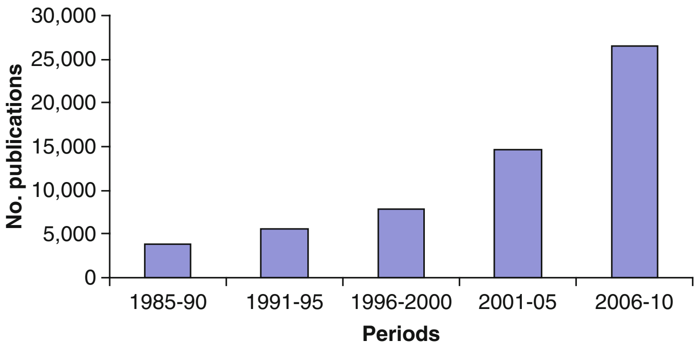


**Fig. 24.1** The number of publications related to the linkage of climate change and agricultural and biological sciences by Science Direct (Based on data from http://www.sciencedirect.com, assessed on March 24, 2010)

*ScienceDirect*, literature on the impact of anthropogenic climate change on agricultural and biological systems dates from the early 1980s, and the number of publications on this subject has rapidly increased since the early 2000s (Fig. 24.1). The studies on this subject mostly rely on simulation models to provide the estimates of the impact of climate change on production (Rosenberg, 2010). For Vietnam in general and the Mekong Delta in particular, studies on the impact of potential climate change and sea-level rise are quite new (e.g., Wassmann et al. 2004; Carew-Reid 2007; ADB 2009; MONRE 2009). These studies, too, rely on simulation models to project the potential impact of future climate change and sea-level rise, based on pre-determined scenarios. In other words, there is still a lack of detailed, site-specific information regarding the climatic impact on agricultural production in the delta. We argue that in the past Mekong Delta farmers have dealt with climatic variability by modifying their farming practices. Understanding climatic effects on *current* agricultural production systems is necessary to identify possible solutions to improving food-production systems in the face of climate change and dealing with food insecurity in the future. By integrating a combination of census-data analysis and participatory community and household appraisals, this essay quantifies the effects of short-term weather variability on rice and aquaculture production, and it subsequently suggests possible ways to improve current agricultural production systems to effectively adapt to future weather variability and climate change.

## 24.2 Materials and Methods

### *24.2.1 Study Framework*

To achieve the objective of the work, the present study integrated analyses of census data from the GSO (2010) and the CSO (2010) with participatory community-appraisal data collected from previous projects.[1] First, principal weather variables that have strongly impacted agricultural production were identified through participatory community appraisals conducted in representative research areas. Second, monthly values of the identified weather variables with different probabilities were calculated, based on data collected from provincial weather stations. Third, critical ranges and occurrence probabilities of the weather variables were identified and estimates of impacts on crop production were calculated with farmers' assessments and linear-regression methods. Finally, farmers' current measures to cope with climate change are described and strategies to adapt to climate variability in the future are suggested.

### *24.2.2 Data Collection*

Participatory community appraisals were conducted in three districts: Vinh Thanh (Can Tho City), Tra Cu (Tra Vinh Province), and An Bien (Kien Giang Province). Vinh Thanh District is located in a flood-prone, freshwater, and irrigated zone, where intensive rice growing with two or three crops a year and freshwater fish culture are considered the major farming activities. The two other districts are located in coastal zones, where rice farming with two crops a year relies heavily on rainfall during the wet season, while black tiger (*Penaeus monodon*) shrimp farming totally depends on saline water from the sea in the dry season. For each district, two representative communes were identified, based on agro-ecological characteristics, from which one representative hamlet per commune was selected for data collection. For each hamlet, different dominant farming systems were determined. Focused group discussions were done with 7–10 people per farming system to get a general understanding of current farming practices, principal weather variables affecting crop production, and their occurrence time. Subsequently, household interviews were conducted with group members to estimate impacts on crop production.

Census data of An Giang, Can Tho, Hau Giang, Tra Vinh, Soc Trang, Bac Lieu, Cau Mau, and Kien Giang in the period of 1990–2008 were collected from yearly statistical books (CSO 2000, 2010; GSO 2010). Variables included monthly air temperature (mean, maximum, and minimum), monthly accumulative rainfall, and yearly yields of rice, fish, and shrimp.

### *24.2.3 Statistical Analysis*

We applied statistical methods to analyze census data. We estimated monthly values of weather variables, which were considered to have significant impacts on crop

[1] (1) Hazard vulnerability and capacity assessments in Can Tho City of Vietnam in 2009, funded by Challenge to Change, and (2) improved agricultural water productivity for poverty reduction in coastal areas of the Vietnamese Mekong delta in 2008, funded by SEI-Asia.

production, and the probability that such values would be exceeded by 10%, 25%, 50% and 75%, assuming that data of the considered variables are log-normally distributed (Shahin et al. 1993). To confirm and further explain results obtained from farmers' assessments, multiple linear regression methods were applied to assess the impact of weather variables on rice, fish, and shrimp yields. To meet the assumptions for multiple linear regression analysis, we tested the normality, the variance homogeneity, the autocorrelation, and the multicollinearity of variables considered. We used the forward stepwise method to select variables. The validity of the results from the representative models was assessed using non-parametric bootstrapping, which creates a validation sample by sampling with replacement from the original sample (Hair et al., 1998). Combined with farmers' observations, the probability and multiple regression analysis allowed us to determine critical values and impacts of extreme temperature and rainfall on rice production.

## 24.3 Results and Discussions

### *24.3.1 Identification of Weather Variables Affecting Rice and Aquaculture*

Results from participatory community appraisals show that anomalies in air temperature and rainfall, which usually occur in the onset of the dry and wet seasons, caused negative effects on rice and fish or shrimp production. Monthly distribution of air temperature and rainfall with probabilities of exceedence ($P$) is shown in Figs. 24.2 and 24.3. Colder days usually take place in December or January (the onset of the dry season) while hotter days are almost always observed in April (the early period of the wet season). In April, the probability of the maximum temperature exceeding 34.5°C, 35°C, 35.5°C, and 36°C is 75%, 50%, 25%, and 10%, respectively (Fig. 24.2b). Similarly, in January, the probability of the minimum temperature exceeding 19°C, 20°C, 21°C, and 21.5°C is 75%, 50%, 25%, and 10%, respectively (Fig. 24.2c).

During the dry season (December–April), rainfall is light and some areas experience droughts. Peak rainfall occurs between July and October. In the irrigated zone, in February the probability of rainfall exceeding 2, 5, and 11 mm is 50%, 25%, and 10% (Fig. 24.3a). In the coastal zone, the corresponding rainfall values at 50%, 25%, and 10% probabilities are 1.5, 2.5, and 12 mm, respectively (Fig. 24.3b). During the dry season with low flows of the Mekong River, salinity intrusion occurs in the lower part of the delta. During the wet months, in contrast, local rainfall, combined with the heavy discharge of water from upstream on the Mekong River, causes monsoon floods in the upper delta between August and November. A combination of local rainfall and the hydrological patterns of the Mekong River determines the seasonal cropping calendar of rice and shrimp culture in both the flood and coastal zones (Fig. 24.4). In irrigated and freshwater zones, rice culture and

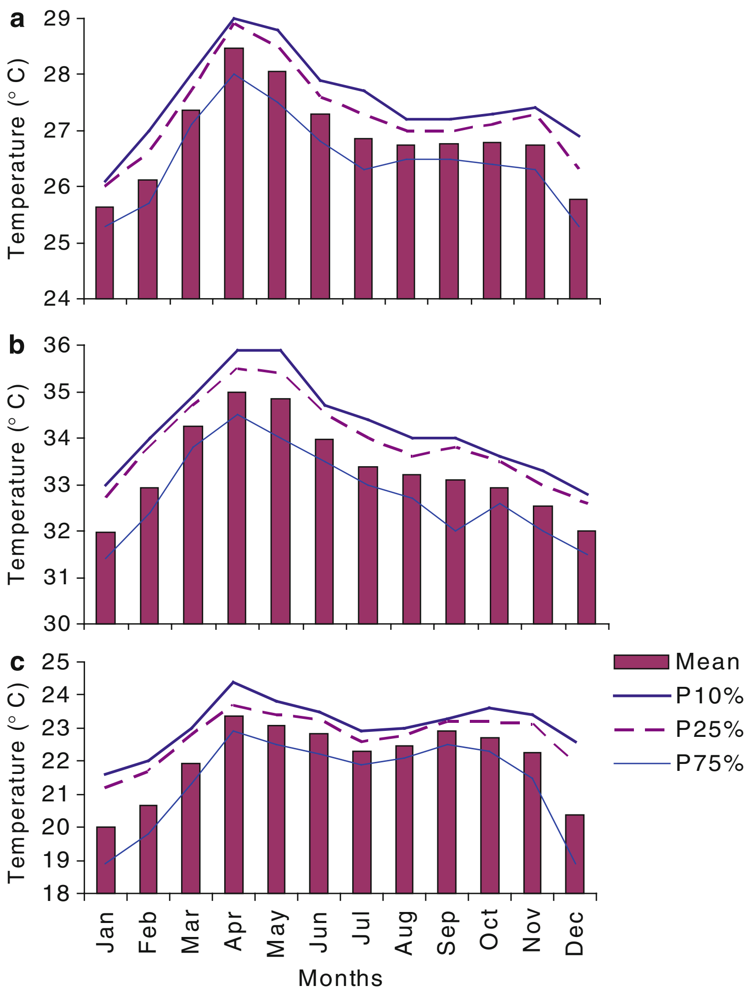


**Fig. 24.2** Monthly air temperature with probability of exceedence ($P$) = 10, 25, 50 (mean) and 75%: (**a**) mean temperature, (**b**) maximum temperature, and (**c**) minimum temperature

aquaculture rely heavily on water from the Mekong River. During flood periods with high and prolonged inundation, however, rice cannot be grown. In the lower part of the delta along the coast, in contrast, rice production totally depends on rainfall during the wet season, while shrimp is grown during the dry season, using saline water from the sea.

In the irrigated zone, according to local people, extremely cold and/or rainy days occurring in January and February, when the rice crop is in flowering and ripening stages, would cause significant losses in the dry season (DS) crop. In addition, in the wet-season (WS) rice crop, abnormally hot days occurring during vegetative stages of the rice plant (April–May) would constrain rice production through limiting

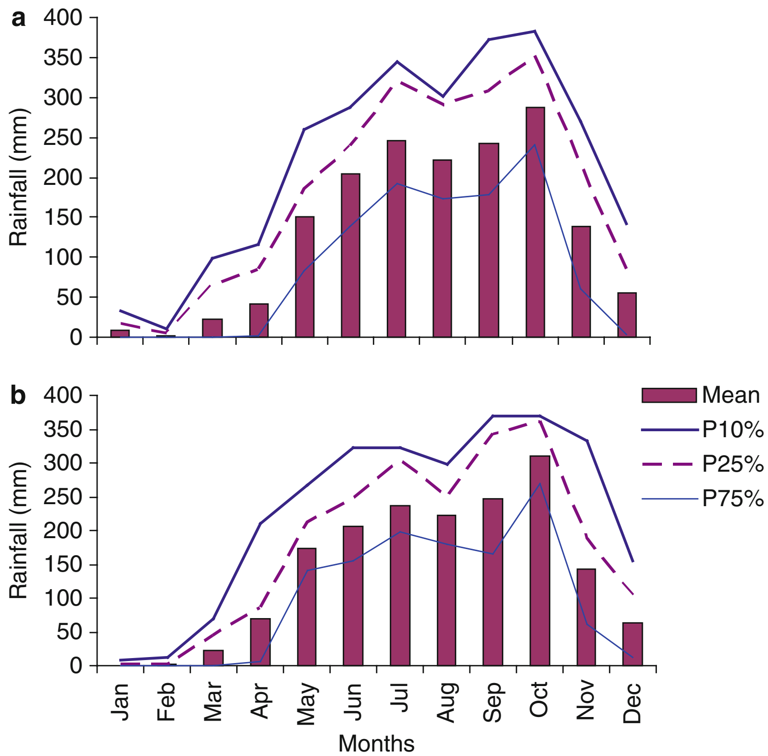


**Fig. 24.3** Monthly rainfall with probability of exceedence ($P$) = 10, 25, 50 (mean) and 75% in the freshwater and irrigated zone (An Giang, Can Tho and Hau Giang provinces) (**a**) and the coastal zone (Tra Vinh, Soc Trang, Bac Lieu and Kien Giang provinces) (**b**)

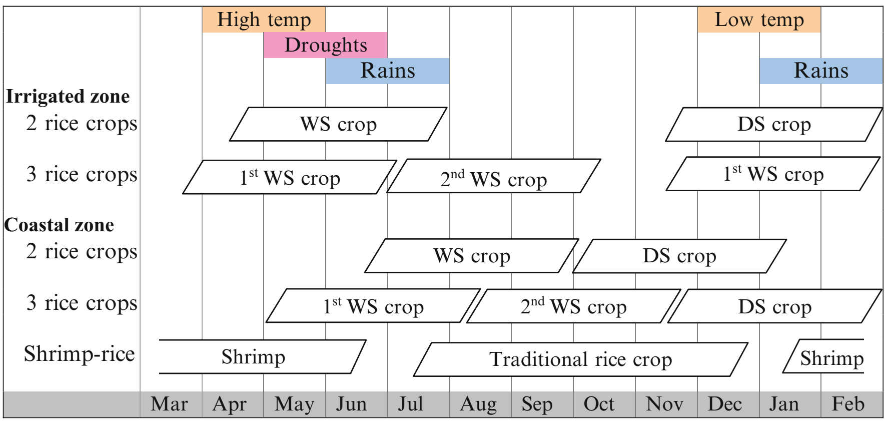


**Fig. 24.4** The occurrence of abnormal weather events and seasonal calendar of rice and shrimp farming patterns in the irrigated zone (An Giang and Can Tho provinces) and in the coastal zone (Tra Vinh and Kien Giang provinces). *Pangasius* catfish culture is practiced year round in the irrigated zone

rice tillering activity and the incidence of rice thrips (*Baliothips bijomio*). Moreover, more cloudy days with heavy rains in June would result in a decrease in yields of the wet-season rice crops through increasing rice-grain sterility.

For intensive *Pangasius* catfish culture, farmers observed that activity and food intake of fish became problematic on days of extremely low temperature in December and January. According to farmers' evaluations, the negative effect of low temperature on *Pangasius* catfish production was reduced by appropriate interventions in farming techniques like deepening ponds, reducing feeding, adding vitamins and minerals into fish feed, and reducing pond water exchange rates.

In coastal areas, rice farmers encounter the same problems as those in the irrigated zone. Rice production is negatively affected by days of extremely low temperature and/or abnormal rains in January–February. In addition, due to rain-fed rice production, the occurrence of droughts in May and June would cause water shortages for rice in vegetative stages and hence lower yields of the wet-season rice crop. Through simulation, Tuan and Chinvanno found that the average maximum temperature in the dry season would increase and that rainfall during the early periods of the rainy season would decrease. In the case of rice production in the coastal zone, adaptive strategies to combat severe drought stress are therefore necessary. For shrimp production, extremely high temperatures in the period of March–May and abnormal rainfall in the dry season would cause big changes in the pond-water environment, which in turn causes shocks for shrimp and hence harvest losses.

## *24.3.2 Assessments of the Impact of Weather Variability*

### 24.3.2.1 Rice Production

Multiple regression analysis confirmed and further explained findings from farmers' assessments. For the irrigated zone, the results showed that yields of the dry-season rice crop were positively affected by minimum temperature in January (i.e., panicle formation and/or flowering stages of the rice plant) and negatively affected by rainfall in January and February (i.e., from flowering, milking to ripening stages) (Figs. 24.4 and 24.5a). These predictor variables explain 15% of the total variability in rice yields. In the wet-season crop, rice yields were negatively affected by mean temperature in May, when the rice plant is in vegetative stages for the double rice-cropping pattern or in panicle-formation stages for the triple rice-cropping pattern. In addition, rice yields decreased with increased rainfall in June. These predictor variables explained 44% of the total variability in rice yields of the wet-season crop (Fig. 24.5b).

For the coastal zone, as in the irrigated zone, abnormal rains taking place in January and February resulted in a significant decrease in yields of the dry-season rice crop (Fig. 24.6a). This rainfall anomaly accounted for 24% of the total variability in rice yields. For the wet-season crop, rice yields tended to be significantly

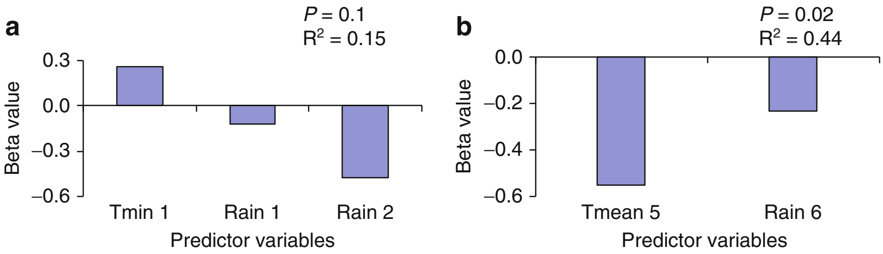


**Fig. 24.5** Standardized partial regression coefficient (beta value) for predictor variables of rice yields in the irrigated zone: (**a**) dry-season crop and (**b**) wet-season crop. Model significance (*P*), adjusted coefficient of the determination ($R^2$), rainfall (Rain), minimum temperature ($T_{min}$), mean temperature ($T_{mean}$). For each predictor variable, the nearby number indicates month. The same explanation is also applied to Fig. 24.6

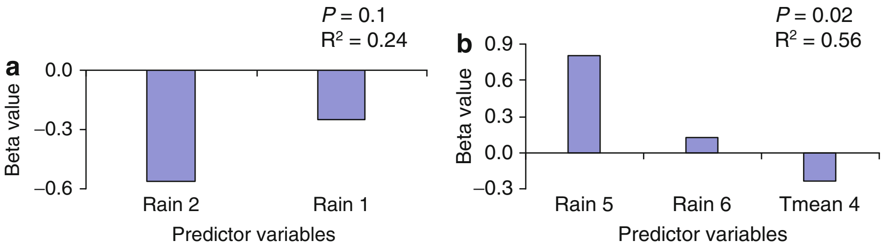


**Fig. 24.6** Standardized partial regression coefficient (beta value) for predictor variables of rice yields in the coastal zone: (**a**) dry-season crop and (**b**) wet-season crop. Model significance (*P*) and adjusted coefficient of the determination ($R^2$)

greater with higher rainfall in May and June and with lower temperature in April (Fig. 24.6b). These predictor variables explain 56% of the total variability in rice yields. In the coastal zone, rice production relies totally on rain water during the rainy season, and rice production is highly susceptible to the occurrence of severe drought stress during early periods of the rainy season. In this zone, droughts lead not only to water shortages for the rice plant but also to soil acidification and salinization, due to acid sulphate soils and salinity intrusion from the estuary, which in turn adds more negative effects on rice production (Nhan et al. 2008). Looking at significance levels (*P*) and coefficients of determination ($R^2$), one can find that the negative impacts of temperature and rainfall anomalies on rice production were more significant during the wet season and for the coastal zone than for the dry-season crop and the irrigated zone, respectively. In adapting rice production in the delta to future weather and climate variability, we therefore need to pay more attention to the wet-season rice crop and to the coastal zone.

Farmers estimated the impact of temperature and rainfall variability on rice production and the frequency of occurrence of abnormal variation for both the dry season and the wet season in the irrigated zone as well as the coastal zone (Table 24.1).

**Table 24.1** Estimates from farmers' perception and statistical analysis on the occurrence and impacts on rice yields of weather variability in irrigated and coastal regions in the Mekong Delta

| | Farmers' estimation | | Statistical calculation[a] | | |
|---|---|---|---|---|---|
| Weather variability by crop | Return period (years) | Yield losses (tons paddy) | Value | Return period (years) | Yield losses (tons paddy) |
| Dry-season crop | | | | | |
| Low temperature in Jan | 3–4 | 0.6 | <19°C | 4 | 0.12 for each 1°C decrease |
| Rainfall in Feb | 3–4 | 0.6 | >10 mm | 4 | 0.3–0.4 for each 10 mm increase |
| Wet-season crop | | | | | |
| Extremely hot temperature in May (irrigated region) | 3–4 | 0.3 | >35°C | 4 | 0.38 for each 1°C increase |
| Heavy rainfall in Jun (irrigated region) | 2 | 0.6 | >250 mm | 2 | 0.2 for each 100 mm increase |
| Droughts in May (coastal region) | 5–6 | 1.8 | <50 mm | 4 | 0.6 for each 100 mm decrease |

[a]Estimates are obtained from multiple regression models (Figs. 24.5 and 24.6)

For the dry-season rice crop, abnormally low temperatures or abnormal rains in January–February were estimated to occur every 3–4 years, which caused yield loss of about 0.6 tons per hectare, accounting for about 10% of the normal yield. For the wet-season rice crop, in the irrigated region farmers perceived that extremely hot temperatures in May occurred every 3–4 years, causing yield loss of 5% of the normal yield. In addition, they estimated that high levels of rainfall in June – levels that would cause yield loss of about 10% of normal yield – occurred every 2 years (Table 24.1). In the coastal zone, in contrast, water scarcity in early rainy periods is an important problem for the wet-season rice. According to local farmers, an extreme drought occurs once every 5–6 years, which would reduce the rice crop by 1.8 tons per hectare, accounting for about 40% of the normal yield.

Based on farmers' estimates of abnormal weather variation, critical values and impacts of extreme temperature and rainfall were determined through both probability and multiple regression methods. As mentioned earlier, statistical results revealed that there is 25% probability that the lowest temperature in December or January is below 19°C. Through a multiple regression equation, it was calculated that in January in the range of 18–22°C, for each 1°C drop, yield decreases by 0.12 tons paddy per hectare in the irrigated region. Similarly, in April with 25% probability that the highest temperature is above 35.5°C, and if the temperature is greater than 34°C, for each 1°C increase the yield would decrease by 0.38 tons of paddy per hectare. Our results are consistent with those of Yoshida (1981) on the critical importance of temperature for the development of rice plants at different growth stages in tropical regions. According to him, extreme temperature at the productive stages of the rice plant, especially at anthesis (i.e., 9 days before and at heading), results in grain sterility in a high percentage of plants.

Similarly, we determined critical rainfall and quantified its impacts on rice production. In February with 25% probability the rainfall was observed to be greater than 10 mm. For each 10-mm increase, a harvest loss is estimated of 0.3 tons of paddy per hectare in the coastal region or 0.4 tons of paddy in the irrigated region. By the same method, we determined critical rainfall in May and June and quantified its impacts on rice production in both irrigated and coastal zones (Table 24.1).

#### 24.3.2.2 Aquaculture Production

Regarding the effects of extreme temperature and rainfall on intensive *Pangasius* catfish production, statistical data analysis did not reveal any significant impact. Farmers' measures in coping with weather variability in *Pangasius* catfish production could be the reason. For shrimp production, the regression analysis shows the significantly negative correlation of mean air temperature in April and in May with shrimp yields (Fig. 24.7). According to this relationship, the variability of mean temperature in April and in May explains about 35% and 21% of the total variance of shrimp yields, respectively. With these correlations, shrimp yields would decrease by 160 kg per hectare or 90 kg per hectare for each 1°C increase (in a range of 27.5 and 29.5°C). The probability of mean air temperature exceeding 28°C is 75% in April and 50% in May (Fig. 24.2a). On hot days in April and May, the maximum temperature of the air usually exceeds 34°C (Fig. 24.2b), which is greater than the optimum temperature range for many shrimp species (Piyakarnchana et al. 1975). Pond water tends to follow the general trends of temperature in the surrounding air. Extremely high temperature would cause, both directly and indirectly, negative effects on shrimp as well as the pond-water environment and hence on growth and survival of shrimp (Delince 1984). Previous studies reported that coastal shrimp farming is economically risky (Preston and Clayton 2003; Joffre and Bossma 2009).

### *24.3.3 Measures of Coping and Adapting to Weather Variability*

#### 24.3.3.1 Coping Measures

Local farmers and extension workers have improved farming techniques and institutions to cope with extreme temperature and rainfall. Coping measures have been mostly applied at the farm level. For irrigated rice production, farmers have applied integrated nutrient management to enhance rice-plant health and allow the rice to better tolerate weather anomalies while reducing agro-chemical input costs. Earlier maturity cultivars with hard straw have been grown to minimize risks of extreme weather conditions in both dry and wet-season crops. For rain-fed rice

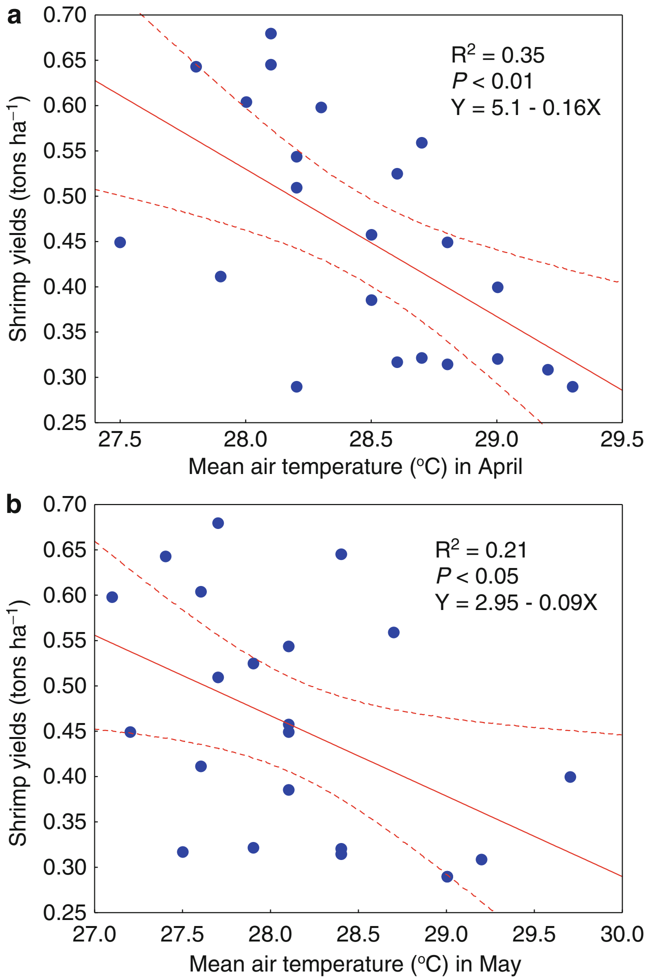


**Fig. 24.7** The relationship of mean air temperature in April (**a**) and May (**b**) with shrimp yields. Regression line with the confident level at 95%, significance (*P*), the coefficient of determination ($R^2$), and the regression equation. Data collected from Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau provinces were employed

production in the coastal zone, the rice crop is determined after consideration of rainfall distribution, the amount of freshwater available in irrigation canal systems, soil moisture content, and mid-range weather forecasts by local weather centers. In addition, farmers have modified their rice fields by digging small ditch systems in order to drain surplus rain water, to store rain water for maintaining soil moisture, and for preventing acidity from moving up from deep soils during soil-oxidation processes. Furthermore, farmers have extracted ground water to irrigate crops in the dry season. This measure, however, is not advocated by the government. The use by farmers of rice cultivars that can tolerate drought, salinity, and/or acidity has still been limited, due to the scarcity of such cultivars.

For intensive *Pangasius* catfish farming, farmers seem to deal effectively with weather variability using appropriate farming techniques as mentioned earlier. For shrimp production, farmers have grown *Scirpus littoralis* (Schrab) in shrimp farms at an appropriate density to stabilize the temperature and aquatic environment of shrimp ponds. In addition, farmers also deepen shrimp ponds or irrigate the pond with a greater amount of water to ensure that the temperature of the pond water does not become too hot. Furthermore, farmers have excavated deep peripheral trenches within the pond for the shrimp to seek shelter on hot days.

Nhan et al. (2008), analyzing the improvement of agricultural-water productivity in the Mekong delta's coastal region, reported that under the same agro-ecological system, water-use ability, and efficiency of resource-poor households are lower than in richer households, even though more support policies are given to poorer people by the government. This would suggest that the effectiveness of various coping measures is also influenced by the resources of households. Coping measures and interventions appear to be not enough to further improve the livelihoods of rural poor people.

#### 24.3.3.2 Adaptation Measures

According to Maclver (1998), "adaptation is an important component of an integrated and balanced strategy to climatic variability. Adaptation is largely a time-dependent, location-specific learning process." A systems approach, which includes integral components regarding agricultural-production systems, food security, rural people's livelihoods, and combined "bottom-up" responses and "top-down" policy making, is needed. Such an approach is not new, but there is a gap between theoretical knowledge and its application in real situations. Successful climate-change adaptation and vulnerability reduction is rarely undertaken with respect to CC alone, and vulnerability reduction appears to be most effective if undertaken in combination with other strategies and plans at various levels (Smit and Wandel 2006).

In recent decades, the Vietnamese government has invested a great deal of money in developing irrigation systems in both irrigated and coastal zones. Such actions have facilitated coping measures by farmers, which seem to be successful at the farm level. For rice, appropriate seeding, proper cognizance of the length of the crop season, and selection and development of rice varieties with short-growth duration with different abilities to tolerate high temperature, drought, and salinity are necessary. For aquaculture, selection and development of fish/shrimp species that tolerate extreme temperature is of great importance in the future. In order to promote adaptation, technical measures need to be integrated to provide farmers a choice of technological packages appropriate for specific contexts rather than one generic package of technologies. A technological package would include relevant components such as adaptive cultivars, site-specific information regarding farming practices and integrated farming systems, and specific advice on how to manage agricultural water so as to adapt to weather and climate variability. In addition, crop-yield forecasting and simulation need to be applied to predict crop growth or production from the time of the forecast up to the time of harvest and to identify measures for minimizing crop vulnerability and risk due to weather fluctuations and climate variability (Bouman et al. 1997). Such risk-reduction measures are still new in the Mekong Delta. Moreover, the fact that at present weather forecasts are only made with lead times of a few days to a few weeks is still a constraint.

In addition, efforts to improve the agricultural sector's ability to adapt to weather and climate variability, which are usually made at farm scale, need to be reconsidered and placed in broader, more dynamic, and more heterogeneous contexts – the livelihoods of rural people and food security, for example – and taken from household, to regional, national, and even global scale (Ingram et al. 2008). In so doing, adaptation options developed will not only be made effective in terms of agricultural production but also more robust in terms of environmental and economic policy. Agriculture production in the delta has faced increasing challenges from weather and climate variability. Such challenges put more pressure on the government to develop appropriate policies to enhance the adaptability of farmers. It is therefore necessary to integrate the "top-down" scenario-based approach with the "bottom-up" vulnerability-perspective approach (Wall and Smit 2005). By assessing the impact of policies, analyzing the adaptability of local people, and identifying the factors that enhance or discourage adaptability, vulnerability assessments can help to improve agricultural policy. In Vietnam, however, the integration of the two approaches seems to be limited.

## 24.4 Conclusions

This essay has focused on the vulnerability of rice and aquaculture to temperature and rainfall variability in both irrigated and coastal zones in the Mekong Delta, and it has suggested strategies to improve the ability of current agricultural systems to effectively adapt to weather and climate variability in the future. Impacts of temperature and rainfall variability differ with different crops, the development stages of crops, and by season and region. The impacts on rice production are more clear-cut than on aquaculture production. Shrimp production is more directly sensitive to weather variability than is *Pangasius* catfish production. The impacts become more severe during the early vegetative, flowering, and ripening stages of rice crops. The wet-season rice crop and the coastal region are more vulnerable to weather anomalies than the dry-season rice crop and the irrigated region. So far, the measures farmers have used to cope with weather variability are mostly immediate ones. Sustainable rice and aquaculture for food security will require adaptation strategies to weather variability and climate change. Technical solutions for coping are available and should be further improved. Policy support for agricultural research and development is of great importance for the realization of such solutions. More attention should be paid to the coastal zone.

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