

Study on assessing the impact of climate change (temperature and rainfall) on rice yield in the Long Xuyen Quadrangle region (LXQR) – Vietnam

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Abstract: The impacts of climate change such as sea level rise, floods, droughts, saltwater intrusion, extreme weather ... are more and more evident. It causes significant damage to the socio–economy of Vietnam, especially the rice farming industry. In Vietnam, over the past 50 years, the average temperature has risen by about 2–3 degrees Celsius and the sea level has risen by about 20 cm. According to the simulation scenarios, it is estimated that by the end of the twenty–first century, compared to the average in the period 1980–2005, the average temperature in Vietnam could increase by 2.3 degrees Celsius, the annual rainfall would increase by about 5%. and the sea level could rise by 75 cm. There are many influencing factors affecting rice yield such as: meteorological factors, hydrology, saline intrusion, farming, pests,... This study, only the change in yield is assessed rice due to the impact of changes in temperature and precipitation in the context of climate change in the LXQR). By using the CROPWAT model to calculate rice yields with temperature changes and rainfall over periods according to climate change scenarios, the results show that under the RCP4.5 scenario when heat If the degree and rainfall increase, the rice yield decreases by 25.4% on average; RCP8.5 rice yield decreased by 25.3% on average.

Keywords: LXQR; Climate change; Cropwat; Rice yield; Assessment of the damage.

1. Introduction

Climate change has been one of the biggest challenges facing people, the negative impacts of climate change on human life are becoming more and more obvious [1–2]. The direct effects of climate change on water resources are abnormal rainfall changes, rising temperatures and extreme weather events such as long–term droughts and mid–to–saturated floods. Climate change will affect water resources and reduce water resources in many places, leading to water scarcity [3]. Water scarcity is a major problem for many developing countries, including Vietnam, especially in relation to agricultural irrigation in the Mekong River Delta (MRD) and the LXQR. where there is a serious shortage of fresh water in the dry season for many different reasons. For rice, the variation of yield and yield has a great participation of hydro–meteorological factors [4]. To estimate and evaluate the impact of hydro–meteorological factors on crop yields in general and rice in particular, the Food and Agriculture Organization (FAO) developed a CropWat model in 1990, based on temperature conditions, precipitation, sunny hours, humidity, wind speed [5–6].

LXQR is a quadrilateral–shaped land in the MRD, located in three provinces of Kien Giang, An Giang and Can Tho. The four sides of the LXQR are the Vietnam–Cambodia border, the Gulf of Thailand, the Cai San canal and the Bassac River (Hau River). The four

corner vertices of this quadrilateral correspond to four cities: Chau Doc, Long Xuyen, Rach Gia and Ha Tien (Figure 1). The LXQR is one of the major food production and processing centers in the MRD. Formerly An Giang, and now Kien Giang is the locality with the largest rice production in the region. This is the area that has positively contributed to the overall achievement of the MRD region.

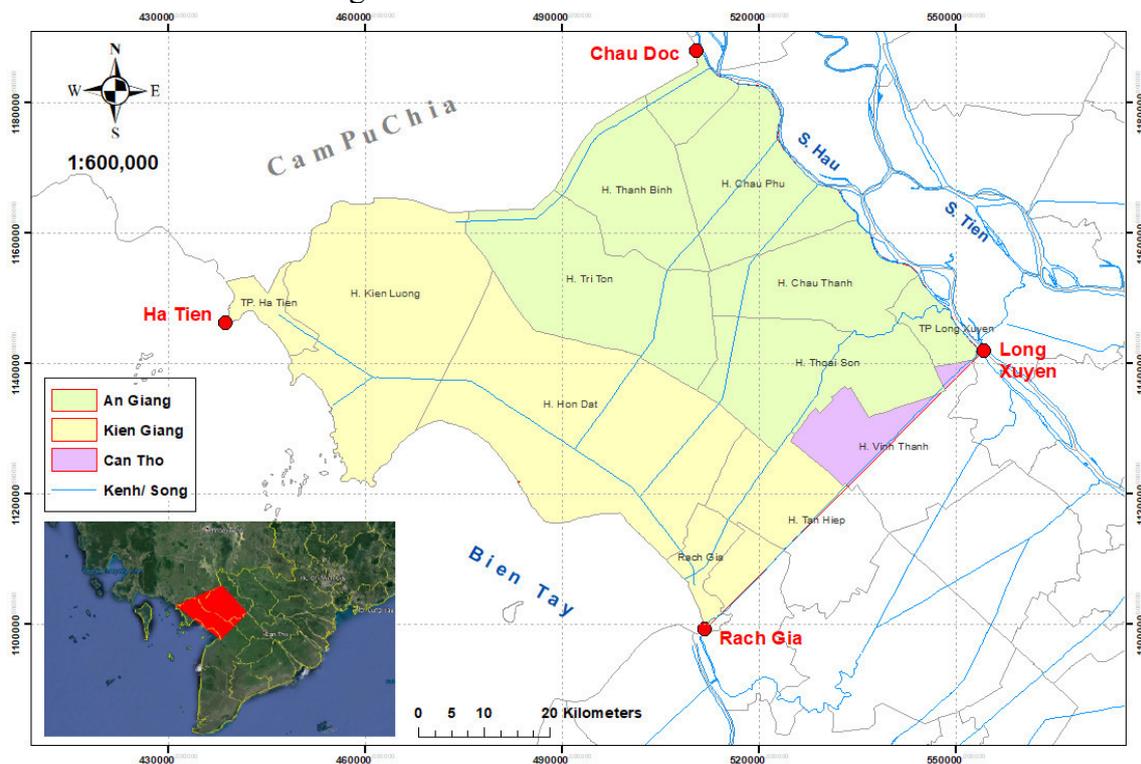


Figure 1. Study area of LXQR.

In the next period, it is forecasted that the LXQR region will face many challenges, in which the issue of climate change and the possibility of droughts, increased saltwater intrusion due to sea level rise. Rice is playing a very important role in the agricultural sector. industry of the region. In Vietnam, over the past 50 years, the average temperature has risen by about 2–3 degrees Celsius and the sea level has risen by about 20 cm [7]. According to the simulation scenarios, it is estimated that by the end of the twenty–first century, compared to the average in the period 1980–2005, the average temperature in Vietnam could increase by 2.3 degrees Celsius, the annual rainfall would increase by about 5%. and the sea level could rise by 75 cm. The change of hydro–meteorological factors in the region can affect crop yield in general and rice yield in particular [8]. The study is conducted to evaluate the impact of hydro–meteorological factors on rice productivity in the study area through future climate change scenarios and thereby calculate the amount of damage caused by the impacts of Climate change through temperature and precipitation factors. The results of this study help to provide useful information for managers in making policies and strategies for the development of agricultural production in the future in the context of global climate change.

2. Materials and Methods

2.1. Methodology

This paper uses CROPWAT 8.0 software, which is the most advanced irrigation regimen software released in 1992, developed and recommended by the FAO for worldwide use. Plant water requirements and irrigation planning based on the data provided by the user [9] (Figure 2).

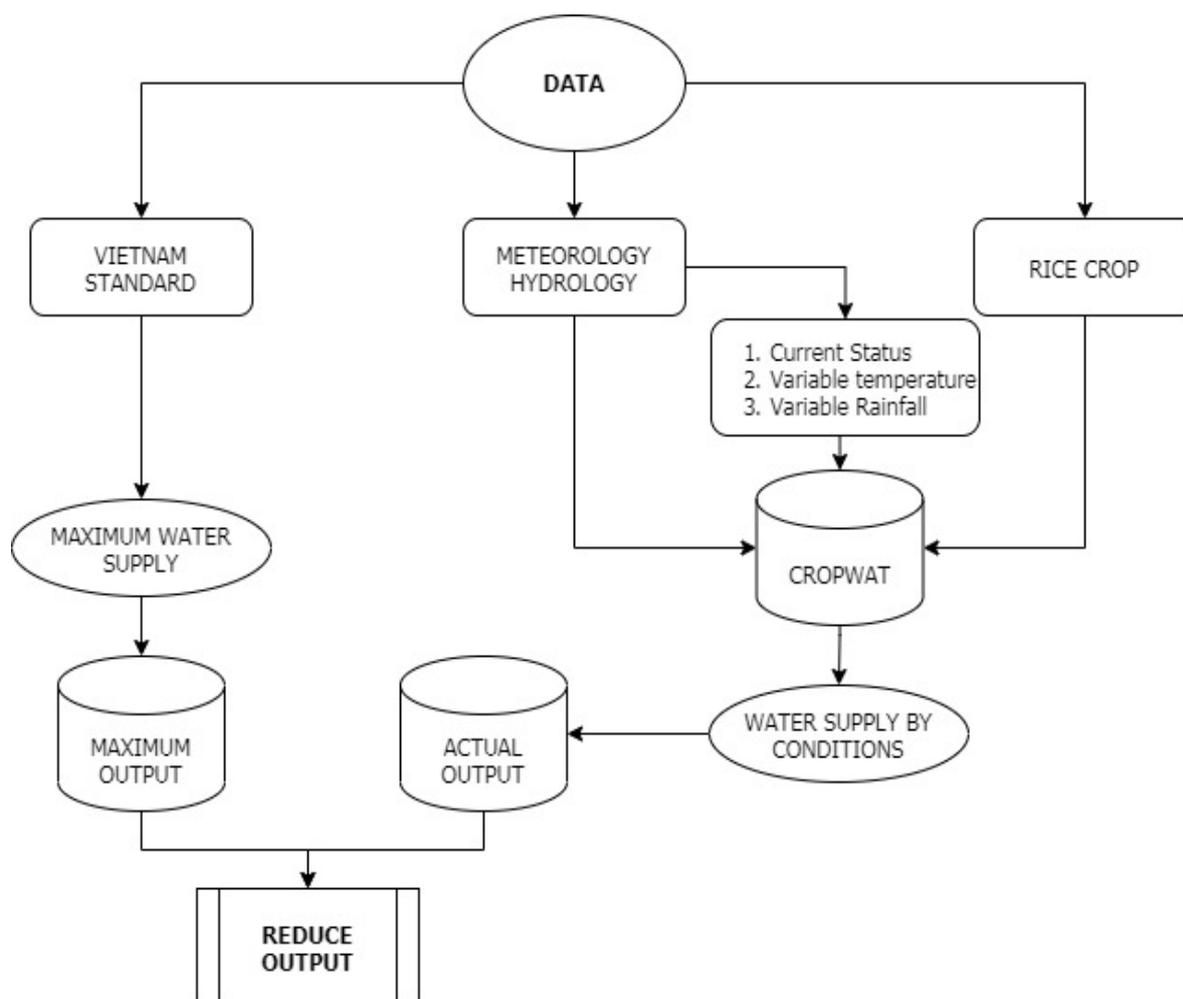


Figure 2. Diagram of implementation steps.

According to [9], the response of crop yield to irrigation water was quantified by a crop yield reduction factor (K_Y), related to a relative yield decrease $(1 - Y_a/Y_m)$ for a Relative water demand deficit $(1 - ET_a/ET_c)$. Therefore, the K_Y values for most crops are based on the assumption that the relationship between relative yield (Y_a/Y_m) and relative water demand (ET_a/ET_c) is linear and has a value for water deficit amounts to about 50% or $1 - ET_a/ET_c = 0.5$.

According to [3], the yield reduction coefficient is of experimental origin (K_y) for the individual growth stages (i.e., establishment, vegetation, flowering, yield formation, or period). segment nine) as well as during total growth.

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y \left(1 - \frac{ET_a}{ET_c}\right) \tag{1}$$

where Y_a is the real yield (corresponding to ET_a) (kg/ha); Y_m is the maximum theoretical yield (corresponding to ET_c) (kg/ha); ET_a is the actual water demand (mm/day) for each crop; ET_c —potential water demand for each crop; K_Y is the yield response coefficient to water stress.

To get the actual yield, multiply the relative seasonal yield by the maximum theoretical yield:

$$Y_a = Y_m \left(1 - K_y \left(1 - \frac{ET_a}{ET_c}\right)\right) \tag{2}$$

Then, the yield price of crops and fisheries is calculated by the formula [9]:

$$\text{Market Value} = Y_a * \text{Area} * \text{Price} \tag{3}$$

where Market Value is the quantity of output of crops/aquatic products (\$); Y_a is an actual yield (kg/ha); Area is the cultivated area (ha); Price is the market price of crop/seafood per unit area (\$/kg) [10–12].

2.2. Data collection

2.2.1. Hydro–Meteorology Data

Meteorological and hydrological data collected up to 2018 provided by the Hydrometeorology Center of An Giang province (Chau Doc station) and the hydrometeorological center of Kien Giang province (Rach Gia station) have been revised, reliable enough, is the basis in calculating the price of agricultural productivity and climate change scenarios in terms of rainfall, temperature, average number of hours of sunshine, humidity, wind speed and other characteristics for this study [13–16].

2.2.2. Socio–economic data

Data on natural conditions, socioeconomic, and agricultural production in the MRD in 2018 are released by the General Statistics Office, the Ministry of Planning and Investment [17–19].

2.2.3. Documents related to rice plants

Rice seasons in the region according to the development stages and Kc coefficients of each growing period of rice are shown in Table 1 and Table 2 below.

Table 1. Rice seasons in the study area [10].

No.	Rice crops	Prepare the land (I)	Initial stage (II)	Development stage (III)	Harvesting stage (IV)	Planting time	Harvest time	Number of days
1	Winter spring Crop	10	10	60	25	15/12	30/3	105
2	Summer– autumn	10	10	65	31	15/4	06/8	111
3	Crop October	10	10	60	20	20/8	30/11	100
	Crop							

Table 2. Kc coefficients of rice plants in the study area [11–12].

Rice crops	Prepare the land (I)	Initial stage (II)	Development stage (III)	Harvesting stage (IV)
Winter spring Crop	0,30	0,54	1,05	0,81
Summer–autumn Crop	1,03	1,19	1,74	1,12
October Crop	1,04	1,17	1,68	1,14

2.2.4. Climate change scenarios

According to the climate change scenarios of the Ministry of Natural Resources and Environment [5], the beginning of the century (2016–2035) between the century (2045–2065) and the end of the century (2080–2099) with 2 scenarios of the emission concentration medium low (RCP4.5) and high (RCP8.5) [20–21].

This study is limited to the study period from the beginning of 2016–2035 and according to that result, the temperature of the period is expected to change (increase) compared to the standard period (1992–2018) at the An Giang meteorological station. And Kien Giang in two scenarios as shown in Table 3 below.

Table 3. Scenario of change in temperature and average rainfall in the period 2016–2035 [6].

	RCP4.5		RCP8.5	
	An Giang	Kien Giang	An Giang	Kien Giang
Temperature (°C)	+0.7	+0.7	+0.9	+0.8
Amount of rain (%)	+4.7	+4.9	+8.2	+6.5

3. Results and discussion

3.1. Effect of temperature on rice yield

The average temperature increase under the RCP 4.5 and RCP 8.5 scenarios is 0.7°C and 0.9°C respectively, generally making the rice yields of the rice growing districts in the LXQR decrease.

Specifically:

In winter–spring crop (WSC), ETc evaporation according to RCP 4.5 scenario is 689.8 mm/day and according to RCP 8.5 is 693.7 mm/day (data extracted from the results simulating the Cropwat model), while the actual water demand is 770 mm/day (TCVN), the water demand is not enough according to reality, thus reducing rice yield. Compared to the maximum yield of the WSC crop (8.00 tons/ha), when the temperature increases by 0.7°C under the RCP 4.5 scenario, the productivity of the WSC 4.5 crop decreases by 10.5% (equivalent to 0.84 tons/ha). When the temperature increased by 0.9°C under the RCP 8.5 scenario, the rice yield decreased 10.0% (equivalent to 0.80 tons/ha. In addition, the WSC coincides with the dry season, the evaporation of water evaporation increases, the water demand for plants is less, rainfall and other factors do not change, so rice yield decreases (Figure 3).

In the summer–autumn crop (SAC), rice yields decreased by 43.3% (equivalent to 2.59 tons/ha) and 43.7% (equivalent to 2.62 tons/ha), respectively. The evaporation of ETc of SAC crop under RCP 4.5 scenario is 956.7 mm/day and under RCP 8.5 scenario is 962.3 mm/day (data extracted from the modeling results of Cropwat), meanwhile Actual water demand is 580 mm/day (TCVN).

In the October crop (OC), rice yield decreased by 24.5% and 25.1%, respectively (decreasing by 1.71 tons/ha and 1.76 tons/ha). The evaporation of ETc of the OC under the RCP 4.5 scenario is 652 mm/day and under the RCP 8.5 scenario is 657 mm/day (data extracted from the modeling results of the Cropwat model), the actual water demand is 500 mm/day (TCVN). The OC also coincides with the rainy season, with a lot of rainfall, the amount of water needed for plants is greater than the actual demand, thus affecting yield. (Figure 3).

In general, when temperature increases, rainfall, humidity, sunny hours, and wind speed do not change, the amount of water evaporation increases, but the amount of water needed for plants is limited, affecting yield rice in crops.

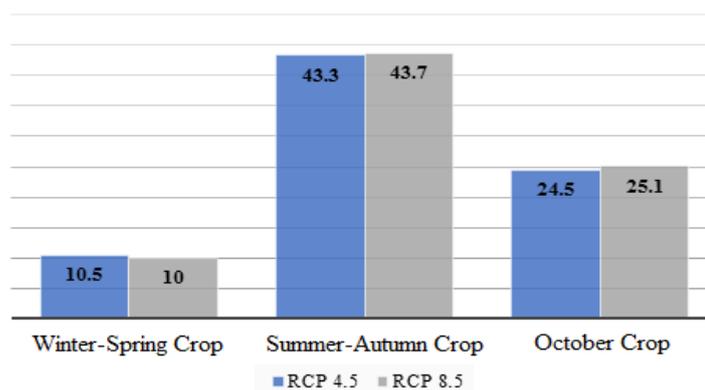


Figure 3. Rate of decrease in rice yield due to the effect of temperature under climate change scenarios (%).

3.2. Effects of changes in rainfall caused by climate change on rice yield

The average rainfall under the RCP 4.5 scenario increased by 4.7% and the RCP 8.5 by 8.2%, in general, both resulted in a decrease in rice yields of the crops.

Specifically:

In Winter–Spring crop, rice yield decreased by 12.2% and 12.5%, respectively (down 0.98 tons/ha and 1.00 tons/ha) compared to the maximum yield of the crop when it rains. increased by 4.7% and 8.2%, respectively. According to simulation results from CROPWAT model, the evaporation of ET_c in the DXP 4.5 scenario is 676.9 mm/day and according to the RCP 8.5 scenario is 674.8 mm/day. The time of the winter season coincides with the dry season, temperature and other meteorological factors do not change, but the future rainfall will increase to exceed the potential water demand of the rice crop, thus affecting the rice yield but not much (Figure 4).

The productivity of Summer–Autumn rice crop also decreased, according to simulation results from CROPWAT model, ET_c evaporation of HT crop under RCP 4.5 scenario was 923.8 mm/day and under RCP 8.5 scenario 915.0 mm/day, while the actual water demand is only 580 mm/day (TCVN). According to the scenarios with increased rainfall, the yield of HT crop rice decreases sharply. Rice yield decreased by 40.9% and 40.3%, respectively (decreasing equivalent to 2.46 tons/ha and 2.42 tons/ha). In general, when temperature and other factors do not change, rainfall greatly affects the yield of SAC (Figure 4).

In the October crop, rice yield decreased by 20.7% and 19.9% respectively (decreasing equivalent to 1.45 tons/ha and 1.39 tons/ha). According to simulation results from CROPWAT model, the evaporation of ET_c of Seasonal crop under RCP 4.5 scenario is 622.8 mm/day and under RCP 8.5 scenario is 616.8 mm/day, meanwhile Actual water demand is 500 mm/day (TCVN) so rice yield is affected (Figure 4).

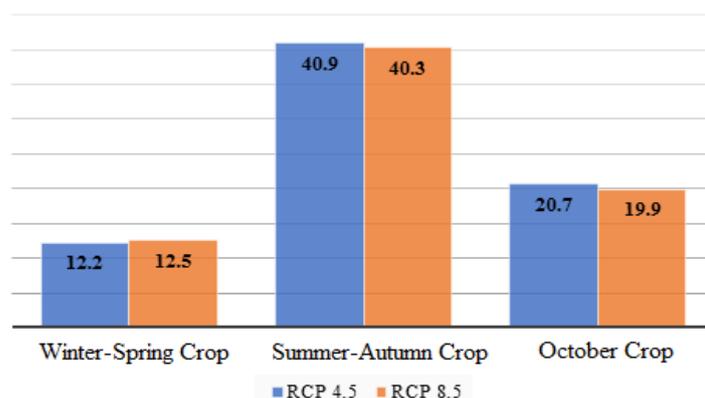


Figure 4. Rate of decrease in rice yield due to the effect of rainfall under climate change scenarios (%).

In summary, when the rainfall increases, the factors of temperature, humidity, sunshine hours, and wind speed do not change, the amount of evaporation will decrease compared to the baseline period, the water demand needed for plants is met. Excess compared to the potential water demand, thus affecting the rice yield in the crops.

4. Conclusions

When the temperature increases, the rainfall, humidity, sunny hours, and wind speed do not change, the amount of water evaporation increases, but the amount of water needed for plants is limited, thus reducing the rice yield. in cases.

When the rainfall increases, the factors of temperature, humidity, number of hours of sunshine, and wind speed do not change, the amount of evaporation will decrease compared to the baseline period, the water demand needed for tall trees is met. With the potential water demand, the rice yield in the crops is also reduced.

In addition to temperature and precipitation, other meteorological factors such as wind, humidity, hours of sunshine,... also affect rice yield and will be considered in later studies. In fact, climatic factors have a mutual relationship: the change of one factor leads to the change of another factor. Therefore, there should be more in-depth studies on the effects of these factors on rice yields in particular and crops in general.

Calculation results in the study have shown the impact of climate change, namely the increase in temperature and rainfall in the Mekong Delta on the rice yield here.

As mentioned from the beginning, the study just stopped at assessing the impact of two independent factors, temperature and precipitation, so the results have not been fully and accurately reflected. These factors will be calculated and included in the evaluation in the next studies.

Author contribution statement: Research ideas, build scientific bases and methods to calculate yield losses of rice crops due to changes in temperature and rainfall due to climate change: C.T.V.; Orientation for data collection and use to calculate water demand for rice plants; Write the manuscript and correct the article; Applying SWAT model to calculate water demand for rice and calculate rice yield according to scenarios: P.T.T.D.; Build a scientific basis to determine the maximum yield of rice and Analyze the calculation results: D.T.N.; Collect, edit, process survey data, survey on the hydro-meteorological situation, economy, society and rice in the TGDXX: L.V.N.; Analysis of local climate change conditions as an input to the calculation model: C.T.V.

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