

# Assessing the impact of climate change on agriculture in Quang Nam Province, Viet Nam using modeling approach

Impact of  
climate change  
on agriculture

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## Abstract

**Purpose** – This study aims to evaluate the impact of climate change on some specific areas of agricultural production in Quang Nam Province, including assessing the possibility of losing agricultural land owing to sea level rise; assessing the impact on rice productivity; and, assessing the impact on crop water demand.

**Design/methodology/approach** – This study used the method of collecting and processing statistics data; method of analysis, comparison and evaluation; method of geographic information system; method of using mathematical model; and method of professional solution, to assess the impacts of climate change.

**Findings** – Evaluation results in Quang Nam Province show that, by the end of the 21st century, winter–spring rice productivity may decrease by 33%, while summer–autumn rice productivity may decrease by 49%. Under representative concentration pathway (RCP) 4.5 scenario, water demand increases by 31.1% compared to the baseline period, of which the winter–spring crop increases by 28.4%, and the summer–autumn crop increased by 34.3%. Under RCP 8.5 scenario, water demand increases by 54.1% compared to the baseline period, of which the winter–spring crop increases by 46.7%, and the summer–autumn crop increased by 63.1%. The area of agricultural land likely to be inundated by sea level rise at 50 cm is 418.32 ha, and at 80 cm, it is 637.07 ha.

**Originality/value** – To propose adaptation solution to avoid the impacts of climate change on agriculture, it is necessary to consider about the impact on losing land for agriculture, the impact on rice productivity, assess the impact on crop water demand and other. The result of this assessment is useful for policymakers for forming the agriculture development plan.

**Keywords** Climate change, Agricultural land, Rice productivity, Water demand

**Paper type** Case study

## 1. Introduction

According to a report by the Intergovernmental Panel on Climate Change (IPCC), global average temperature and sea level have increased rapidly over the past 100 years, especially in the past 25 years. Temperatures have tended to increase at most observation stations,

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This paper was completed within the framework of the state-level science and technology research project: “Researching scientific and technological solutions for multidisaster management, developing tools to support decision-making and coping with multiple natural disasters, pilot application to the Central coastal region under the Program: Scientific and technological research for environmental protection and natural disaster prevention” Code: KC.08/16–20.



increasing rapidly in recent decades (IPCC, 2007). In Viet Nam, the average annual temperature during the period of 1958-2014 increased by about 0.62 Celsius degree, in the period (1985-2014), the temperature increased by about 0.42 degree. On average, the water level at the Vietnamese naval stations tends to increase significantly with an increase of about 2.45 mm/year. The phenomenon of El Niño and La Niña increasingly strongly affects the climate and weather of Viet Nam. Climate change has really made natural disasters, especially typhoons, floods and droughts, increasingly fierce.

Agriculture around the world has been identified as an important and significant contributor to the economy. For Viet Nam, agriculture has considered a key and important economic sector with more than 70% of the population working in agriculture and living in rural areas. In recent years, under the impact of climate change, the frequency and intensity of natural disasters have been increasing, causing great losses of people, assets, infrastructure, economy, culture, society and bad impact on the environment.

Climate change is increasingly seriously affecting production, life and the environment worldwide; making comprehensive and profound changes in global development and security processes such as food, water and energy, social, cultural, diplomatic and commercial issues. Agriculture is one of the sector that most vulnerable to climate change. Therefore, assessing the impact of climate change on agricultural production is one of the important issues to support the proposal and implementation of climate change response solutions to develop agriculture in a sustainable way.

The main impacts of climate change on agricultural production in ecological regions of the world are reflected in the following aspects (IPCC, 2007; Hoa, 2013):

- The increase in temperature will affect the ability to generate and develop crops and animals leading to productivity and output change.
- Increasing temperature will reduce water resources, many areas will have no water and will not be able to continue farming, leading to a decrease in cultivated area.
- An increase in temperature will cause the ice to melt, leading to more invasive, flooded and mangrove lands.
- Changing climate conditions will reduce biodiversity, cause ecological imbalance, especially natural disasters, natural enemies and affect plant growth and disease development.
- Extreme, irregular weather phenomena such as early, late, or unseasonal rains will make it difficult to arrange planting seasons and crop structure, causing significant damage to the agricultural production.

The year of 1998 was considered the hottest year and had severe damage caused by natural disasters such as typhoons in central America; in China, India and Bangladesh, Argentina and Paraguay, floods directly cause serious damage to crops. In addition, little and unseasonal rainfall indirectly affect crop failure in Maharashtra, India.

The European Union experienced a prolonged heat wave in the summer of 2003. Other countries such as Bihar, western Bangladesh, Orissa and Andhra also suffered a hot and harsh summer. In contrast, India experienced a severe cold season from December 2002 to February 2003. Some areas such as Jammu, Punjab, Himachal, Uttar Pradesh and some countries in the western north experienced an unpredictable cold winter. These changes cause crop failures between 10% and 100% in agriculture and cause even more damage to regions with cold and prolonged climates (Samra *et al.*, 2004).

The rising temperature in March 2004 also had a very negative impact on crops such as wheat, apples, peaches, potatoes and herbs throughout Himachal Pradesh state in India.

The highest temperature in the whole of Himachal Pradesh state in March was recorded higher from 2.1 to 7.9 Celsius degree. The amount of crop loss is estimated at 20% to 60% depending on the type of crop (Prasad and Rana, 2006). In addition, due to the increase in temperature from 1 to 3 degree from mid-February to mid-March 2004, in the central region of Kerala, India, the cocoa crop decreased by 39% when compared to 2003 (NIAEM, 2012).

In Haryana and Punjab, India, in 2007, unseasonal rain and hail destroyed the entire wheat crop with an area of 15,000 hectares. Also in this year, during the monsoon season in August, heavy rains inundated many countries including India and Bangladesh. By October, heavy rains caused serious flooding in Andhra Pradesh, Karnataka and Kerala, so 2007 was considered a year of flooding in India. Similar to India, severe flooding also occurred in some countries such as Algeria, Uganda, Sudan, Bangladesh causing severe crop failures (NIAEM, 2012).

In Beijing, China, the temperature soared to 16 Celsius degree in February 2007, the highest recorded by the meteorological agency since 1840 and then followed by the coldest and most snowfall in the winter of 2008. A three-week heavy snowfall near mid-February 2008, caused 104 million hectares of crop damage and about 22,000 houses were destroyed with estimated losses of up to \$7.5bn (NIAEM, 2012).

Along with heavy rains and floods, sea level rise are also obvious manifestations of climate change. Each year, the sea level rises by less than 1 mm along the coast of India. Sea level rise can cause the coastal strip of the region to disappear, altering ocean biodiversity and threatening coral habitats. Especially, when the water is high due to typhoons, combined with strong winds and high tides, the phenomenon of extreme sea level rise will greatly affect the cultivated areas (NIAEM, 2012).

According to the United Nations Food and Agriculture Organization (FAO) report, India is suffering 125 million tons of grain losses. Equivalent to 18% of the country's total product volume due to climate change effects as of 2015. Climate change also reduces grain production worldwide, leaving 400 million people facing hunger and 3 billion people affected by floods and clean water shortages. Crop losses due to climate change may lead to an increase in the number of undernourished people, greatly affecting the process of hunger eradication, poverty alleviation and food security. The region with the most severe climate change impacts is sub-Saharan Africa, which has the least ability to adapt to climate change and must increase food imports to make up the shortage. For example, in 2004 and 2005, 24 sub-Saharan African countries faced a state of emergency over food shortages caused by a combination of locusts and drought. In addition, hot and dry weather in the USA and drought in some parts of the European Union reduced grain production in 2005 when compared to 2004 (NIAEM, 2012).

Climate change has a great impact on India's economy because it is an agricultural country, dependent mainly on cultivation. In 2002, a typical example showed that India's food production depended heavily on the rainy season, but due to climate change during this period, drought occurred throughout the territory of India. The rainfall deficit is about 19% of the multi-year average, resulting in 29% of India's territory being affected by drought, so that food production was seriously affected and decreased by 19.1% compared to the same period (NIAEM, 2012).

Viet Nam is an agricultural country, so that, the agricultural economy has always played an important role in Viet Nam's socio-economic development with a contribution of about 20% of gross domestic product (GDP) (Nghia, 2017; Lan, 2019). The majority of the poor in Viet Nam relies on agriculture. Agricultural and rural areas account for nearly 70% of the country's population. The two major deltas of Viet Nam, the Red River Delta and the Mekong Delta, are now providing food for the whole country and for world exports (Natural Resources and Environment, 2018), Viet Nam is ranked by the United Nations Development Organization as one of the countries most affected and most vulnerable to climate change (Lan, 2019).

According to research results of the University of Copenhagen, Viet Nam's economy will maintain and continue to grow at a rate of 5.4% per year in the period of 2007-2050 and agriculture's contribution to GDP will decrease from 16% to only 7.6%. Sea level rise scenarios show that, although the impacts are mild, they also cause GDP in the period 2046-2050 to decrease from 0%–2.5%. Specifically, if GDP is forecast to reach greater than \$500bn by 2050, the value of damage due to climate change will be around \$40bn (Lan, 2019).

Climate change and extreme natural disasters are no longer a threat that actually exists in Viet Nam (Nhat, 2019). Climate change has been strongly impacting on Viet Nam's agriculture sector, such as reducing agricultural land, increasing drought and pests, putting enormous pressure on the development of the cultivation process (Lac, 2020). In 2018, natural disasters have occurred continuously across the country in Viet Nam with 13 storms and tropical depressions; 212 thunderstorms and tornadoes of lightning; 14 flash floods and landslides; nine strong winds on the sea; four cold spells, damaging cold; 11 heat waves; 23 episodes of cold air; 30 heavy rains on a large scale; major floods in the upstream of the Mekong River after seven years since 2011, the spring tide has surpassed the historical landmarks in the Southern provinces; river bank erosion, severe coastal erosion in the central region and the Mekong Delta, causing serious economic losses with an estimated VND 20,000bn and making 218 people dead and missing (Nhat, 2019). Natural disasters and extreme weather events tend to increase, causing great disadvantages to agricultural production. Strong storms damaged irrigation works, dike systems and devastated crops. Severe cold weather can cause severe damage to newly planted rice and rice. Severe drought causes great losses for rice and other crops such as coffee, pepper, avocado and cashew (Thanh and Viet, 2014).

Climate change makes the water demand for agriculture increase, while the water supply capacity of irrigation works cannot fully meet the demand for irrigation water. The shortage of irrigation water for crops, especially rice, is expected to worsen. Rainfall change and uneven distribution adversely affect the yield and productivity of rice and other crops. Unusual heavy rains and unseasonal rain can cause flooding, leading to inundation of rice, crops and crops (Thanh and Viet, 2014). In addition, saline intrusion into the interior has led to a shortage of agricultural land and salinity affected negatively food security. The area of saline soils in the Mekong Delta is at increasing risk. If the sea level rises by 100 cm, Mekong Delta and Ho Chi Minh City will be at the risk of losing 40.5% of the total rice production of the region (Thanh and Viet, 2014).

In recent years, droughts and heat waves have been continuously and continuously occurring in all regions of the country, showing an increasing level of influence of climate change. Drought reduces 20%–30% of crop productivity, food production, leading to serious impacts on people's livestock and daily life (Nhat, 2019; Lac, 2020). In addition, increased temperatures and drought leading to lack of water will greatly affect the distribution of crops, especially reducing productivity. Specifically, the rice yield of the spring crop tended to decrease more sharply than that of the spring crop; and winter maize yield tends to increase in the Northern Delta and decrease in the Central and Southern regions. It is estimated that the yield of spring rice in the Red River Delta could be reduced by about 3.7% in 2020 and by 16.5% in 2070; Summer rice productivity will decrease by 1% in 2020 and by 5% by 2070 if effective and timely measures are not taken (Dat *et al.*, 2019).

Flooding due to sea level rise will gradually reduce agricultural land. If the sea level rises by 1 m, it is estimated that 40% of the Mekong Delta area, 11% of the Red River Delta area and 3% of the other provinces' areas will be flooded (Viet Nam Ministry of Natural Resources and Environment, 2016). Currently, Viet Nam's cultivated land area is about 9.4 million hectares, of which, 4 million hectares is rice-growing land (Dat *et al.*, 2019).

According to research and forecasts by the IPCC and the World Bank, in Viet Nam, if the water level rises to 1 m, 0.3–0.5 million ha in the Red River will be flooded (Nhat, 2019). On a national scale, Viet Nam will lose about 2 million hectares of rice land, equivalent to about 50% if the sea level rises by 1 m (Dat *et al.*, 2019).

Climate change also increases saline intrusion in coastal areas, causing agricultural land area to be lost, especially in the Mekong Delta (Dat *et al.*, 2019). Based on a multi-year database, the Can Tho City Center for Natural Resources and Environment Monitoring predicts that, by the year 2050, in the dry season, salinity of 1% could penetrate into Can Tho more often with a depth of 0.5 m (Southern Institute of Agricultural Science and Technology, 2013). According to Dat *et al.* (2019), if the sea level rises by 1 m, about 1.77 million hectares of land will be contaminated with alum and salinity, accounting for about 45% of the land area in the Mekong Delta and about 85% of the people in the Mekong Delta region will need agricultural support.

Climate change also increases natural disasters, causing crop yields and real yields to decline. According to the report of the Asian Development Bank, if the temperature increases by 1 Celsius degree, the rice yield will decrease by about 10%, this situation will seriously threaten national and food security and affect the tens of millions of people across the country. According to calculations and forecasts of the Institute of Agricultural Environment, climate change causes the yield of some key plants to decline sharply. Specifically, the yield of the spring crop will decrease by 0.41 tons/ha by 2030 and 0.72 tons/ha by 2050. The yield of maize is likely to decrease by 0.44 tons/ha by 2030 and 0.78 tons/ha by 2050. By 2100, if the sea level rises by 100 cm, the Mekong Delta is likely to be inundated about 89,473 ha, corresponding to the area that will lose about 7.6 million tons of rice/year. Viet Nam will be in serious danger of food shortage and increase poverty rate (Nhat, 2019).

In addition, climate change can affect seasons, change the crop patterns, increase epidemics and reduce productivity and production (Dat *et al.*, 2019).

Losing farmland and declining crop yields will pose challenges and threats to farmers' livelihoods, rice exports and national food security, especially for a country where agriculture plays an important role in the national economy like Viet Nam. If climate change is strong, agriculture will suffer very heavy losses, Viet Nam will face the risk of severe food shortage due to the loss of large rice production, leading to food security for tens of millions of people will be seriously threatened (Dat *et al.*, 2019).

Within the framework of this study, the working group evaluated the impact of climate change on some specific areas of agricultural production in Quang Nam Province, including: assessing the possibility of losing agricultural land due to sea level rise; assess the impact on rice productivity; assess the impact on crop water demand. Evaluation results will be the basis for proposing appropriate adaptation solutions.

## 2. Method used in assessing the impact of climate change on agriculture

### 2.1 Method of collecting and processing statistics data

This method is very important when conducting research in general and assessing the impact of climate change on agriculture in particular. The analysis, evaluation and aggregation of the information obtained to produce official results according to the research objectives.

The data to be collected in this study include:

- Data related to agriculture (area, crop yield) were collected from Statistical Yearbook of Quang Nam Province, 2000-2018.
- Data on damage caused by natural disasters to agriculture (area, crop yields) were collected from Statistical Yearbook of Quang Nam Province, 2000-2018.

- Meteorological-hydrological data series (temperature, precipitation, total hours of sunshine, humidity, [...]) were collected at the meteorological and hydrological stations in the study area within 20-30 years for analysis of climate changes.
- Data of climate change scenarios was developed based on climate change and sea level rise scenarios for Viet Nam (developed by [Viet Nam Ministry of Natural Resources and Environment, 2016](#)).

### *2.2 Method of analysis, comparison and evaluation*

The analysis, comparison and evaluation method was used in studying the impact of climate change on agriculture to serve the comparison of calculation results to reach conclusions related to the research issue. The data of agricultural production in the past, present and future periods have been interpreted in a transparent and logical manner.

### *2.3 Method of geographic information system*

When assessing the impact of climate change on a research area, a number of maps can be developed to serve the evaluation objectives such as natural maps, socio-economic conditions maps; maps of meteorological conditions; map of current agricultural production; map of flood risk classification according to climate change scenarios.

### *2.4 Method of using mathematical model*

#### *2.4.1 Decision Support System for Agrotechnology Transfer – calculating crop yield.*

Decision Support System for Agrotechnology Transfer (DSSAT) is used in calculating crop yield. The software is a product of collaboration between scientists at the University of Georgia, Guelph University, University of Hawaii, WA State University, International Center for Soil Research and Agricultural Development at Politecnica University, Madrid, and the scientists from ICASA center. The DSSAT system consists of three main parts:

- (1) a data management system used to enter, store and recover the necessary data;
- (2) a set of programs to simulate the interaction between genotypes of plants with environment; and
- (3) an application program to analyze and display experimental results ([Gordon et al., 1998](#)).

The DASAT model requires daily weather data, soil surface and profile information and detailed crop management as input. Crop genetic information is defined in a crop species file that is provided by DSSAT and cultivar or variety information that should be provided by the user. Simulations are initiated either at planting or prior to planting through the simulation of a bare fallow period. These simulations are conducted at a daily step or in some cases, at an hourly time step depending on the process and the crop model. At the end of each day, the plant and soil water, nitrogen, phosphorus and carbon balances are updated, as well as the crop's vegetative and reproductive development stage.

*2.4.2 CROPWAT – calculating water demand for agriculture.* Giovanni Monuz proposed a computer program for irrigation planning and management (CROPWAT) 8.0 model to calculate irrigation needs, irrigation regimes and irrigation plans for crops under different conditions ([Giovanni, 2000](#)). CROPWAT program has been widely applied in many parts of the world not only because it is a progressive, complete, modern content program but also because it is very convenient and easy to use.

Version 8.0 of CROPWAT has made significant improvements over the previous versions. Wet rice has been included in the model by the developers. Inputs can be

entered as dates compared to the month time step in previous versions. Calculations and outputs are based on the CROPWAT version 8.0, available at the FAO website ([www.fao.org/agl/aglw/cropwat.htm](http://www.fao.org/agl/aglw/cropwat.htm)).

Calculations of water and irrigation requirements use inputs of climatic, crop and soil data, as well as irrigation and rain data. The climatic input data required are reference evapotranspiration (monthly/decade) and rainfall (monthly/decade/daily). Reference evapotranspiration can be calculated from actual temperature, humidity, sunshine/radiation and wind-speed data according to the FAO Penman–Monteith method (Allen *et al.*, 1998).

### 2.5 Method of expert consultation

This method was used to mobilize the experience of relevant experts. This method is conducted through seminars, consultation workshops. During the evaluation process, seminars need to be organized at different levels to get comments from experts for adjustment of the results.

## 3. Study area

Quang Nam is a coastal province in the key economic development region of the Central of Viet Nam (Figure 1). The total natural area of the province is 1,043,836.96 ha. Quang Nam currently has 18 districts and cities, in which, there are two big cities: Tam Ky and Hoi An. Quang Nam plays an important role in the exchange of goods between the South and the North of Viet Nam via National Road 1 A and Ho Chi Minh Road. In addition, Quang Nam also plays an important role for goods exchange between provinces in the Central region and Central Highlands of Viet Nam. The west of province borders with Laos, which is a



**Figure 1.** Map of river system in Quang Nam Province

Source: Huynh (2020)

favorable condition for goods trade. Quang Nam also has a coastline of more than 125 km, an exclusive economic zone of more than 41,000 km<sup>2</sup>, which will be a condition for the development of the fisheries industry. Adjacent to Da Nang province, is considered a key province for economic development in the central region and located in Chu Lai – Dung Quat high-tech open economic zone. Thus, it can be said that the geographical position of Quang Nam Province has contributed to giving the province quite a lot of advantages in exchanging and trading goods with domestic and foreign regions, creating favorable conditions for economic development of multidisciplinary and multi-sector, making the provincial economy more and more solid.

Agriculture in Quang Nam Province has been heavily affected by climate change in recent years. Specifically, the crop patterns has changed markedly (from three crops to two crops per annum), productivity, crop yield and water demand for crops are facing great challenges in the context of frequent and prolonged droughts. In addition, a number of new diseases have appeared in livestock raising affecting activities of the local livestock industry.

#### 4. Climate change scenario for Quang Nam Province

The climate change scenarios for Quang Nam Province were extracted from the climate change scenarios developed for entire Viet Nam by Ministry of Natural Resources and Environment. In the development of climate change scenarios for Viet Nam, five Global and Regional climate models were used for calculations, namely, AGCM/MRI from Japanese Meteorology Research Institute; PRECIS from Hadley Center, UK; CCAM from CSIRO, Australia; RegCM from ICTP, Italy; and cWRF from NCAR, USA. Each RCM is driven by GCMs from IPCC AR5. In total, there are 12 used members to update climate change scenario for Viet Nam. Details about the climate change scenarios for Viet Nam can be found in [Viet Nam Ministry of Natural Resources and Environment \(2016\)](#).

Under the impact of climate change, in the 21st century, the annual average temperature and rainfall in Quang Nam Province have specific changes compared to that of the baseline period (1986-2005).

According to the representative concentration pathway (RCP)4.5 scenario, in the middle of the 21st century, the average annual temperature in Quang Nam Province increased to 1.4°C and 1.8°C at the end of the 21st century (period 2080-2099). According to RCP8.5 scenario, in the middle of 21st century, the average annual temperature in Quang Nam Province increased by 1.3°C. By the end of the century, the annual average temperature increased by 3.2°C.

According to RCP4.5 scenario, in the middle of 21st century, the average annual rainfall in Quang Nam Province tends to increase by 24.9% compared to the baseline period. By the end of the 21st century, the average annual rainfall change will increase to 25.9%. According to RCP8.5 scenario, in the middle and the end of the 21st century, the average annual rainfall tends to increase in Quang Nam Province with an increase of 25.9% and 29.9% compared to the baseline period.

From [Table 1](#), some observations on sea level rise scenario of Quang Nam Province can be made as follows:

- According to RCP 4.5 scenario, in 2050, the sea level rise in Quang Nam will range from 13.9–32.1 cm with an average value of 22.4 cm. By the end of the 21st century the values will be 32.9–76.0 cm with an average of 53.0 cm.
- According to RCP 8.5 scenario, in 2050, sea level rise in Quang Nam will be from 17.1 to 35.0 cm with the average value of 25.2 cm. By the end of the 21st century the corresponding values will be 50.0–102.2 cm with an average of 73.6 cm.



From Climate change and sea level rise scenarios of Viet Nam, inundation area corresponding to sea level rise of 50, 80 and 100 cm in Quang Nam Province can be summarized in [Table 2](#) (Viet Nam Ministry of Natural Resources and Environment, 2016).

It can be found that, corresponding to each level of sea rise, the inundated area due to sea level rise in Quang Nam Province is different, the flooded area is concentrated in districts: Dien Ban; Duy Xuyen; Nui Thanh; Que Son; Thang Binh; Hoi An City; Tam Ky City; and Phu Ninh district. The flooded areas are mainly concentrated in coastal districts in Quang Nam Province. [Table 3](#) shows that: with a sea level rise of 50 cm, the total inundation area is 1,844.21 ha; with the sea level rise of 80 cm, it is 2,669.40 ha and with the sea level rise of 100 cm, it is up to 3,365.63 ha (an increase of 695.83 ha compared to the sea level rise of 80 cm; 1,521.02 ha compared to the sea level rise of 50 cm).

## 5. Result and discussion

### 5.1 Impact of climate change on agricultural land

This study has calculated the possibility of flooding due to sea level rise for agricultural land of Quang Nam Province at sea level rise of 50 cm and 80 cm. According to the climate change scenarios, it is estimated that by the end of the 21st century, the SLR in Quang Nam is about 32.9 ÷ 76.0 cm with an average value of 53.0 cm (RCP 4.5) and 50.0 ÷ 102.2 cm and

Scenarios/year	2020	2030	2040	2050	2060	2070	2080	2090	2100
<i>RCP 4.5</i>									
High	12.1	18.0	24.7	32.1	41.3	49.1	58.1	67.2	76.0
Medium	8.40	12.5	17.2	22.4	28.1	34.2	41.5	46.9	53.0
Low	5.20	7.80	10.7	13.9	17.5	21.2	25.2	29.1	32.9
<i>RCP 8.5</i>									
High	11.4	18.0	25.9	35.0	45.4	57.0	70.2	85.1	102.2
Medium	8.20	12.9	18.6	25.2	32.7	41.1	50.5	61.3	73.6
Low	5.60	8.80	12.7	17.1	22.2	27.9	34.3	41.6	50.0

Note: Unit: cm

Source: Viet Nam Ministry of Natural Resources and Environment (2016)

**Table 1.**  
Scenario of sea level  
rise due to climate  
change in Quang  
Nam Province

District	Inundation area (ha) (sea level rise 50 cm)	Inundation area (ha) (sea level rise 80 cm)	Inundation area (ha) (sea level rise 100 cm)
Điện Bàn	76.46	209.30	364.10
Duy Xuyên	189.10	287.00	384.20
Núi Thành	712.00	852.80	932.00
Quế Sơn	51.16	97.91	119.20
Thăng Bình	282.60	634.40	924.20
Hội An	230.90	248.40	265.80
Tam Kỳ	300.10	332.40	364.60
Phú Ninh	1.89	7.19	11.13
Other	0	0	0
Total	1,844.21	2,669.40	3,365.23

Note: Unit: ha

Source: Viet Nam Ministry of Natural Resources and Environment (2016)

**Table 2.**  
Inundation area  
corresponding to sea  
level rise of 50, 80  
and 100 cm in Quang  
Nam Province

**Table 3.**  
Inundation  
agricultural land  
with sea level rise of  
50 and 80 cm in  
Quang Nam Province

No.	District	Inundation area (ha) (sea level rise 50 cm)	Inundation area (ha) (sea level rise 50 cm)
1	Núi Thành	144.56	191.39
2	Tam Kỳ	142.59	157.13
3	Duy Xuyên	39.12	110.60
4	Thăng Bình	35.29	72.89
5	Điện Bàn	27.30	63.46
6	Quế Sơn	19.56	26.62
7	Hội An	8.98	11.75
8	Phú Ninh	0.83	2.88
9	Nông Sơn	0.09	0.36
	Total	418.32	637.07

**Note:** Unit: ha  
**Source:** Huynh (2020)

73.6 cm (RCP 8.5), respectively (Viet Nam Ministry of Natural Resources and Environment, 2016). By using the method of overlaying maps of inundation due to sea level rise announced by the Viet Nam Ministry of Natural Resources and Environment in combination with the Quang Nam Land Use map of 2015, the research team have calculated the agricultural land area that could be flooded corresponding to SLR and 50 cm and 80 cm.

From Table 3, it can be found that:

- When the sea level rises by 50 cm, the area of agricultural land likely to be flooded is 418.32 ha. In particular, ranked from high to low districts/cities with land areas likely to be flooded as follows: Nui Thanh (144.56 ha); Tam Ky City (142.59 ha); Duy Xuyen (39.12 ha); Thang Binh (35.29 ha); Dien Ban (27.30 ha); Que Son (19.56 ha); TP Hoi An (8.98 ha); Phu Ninh (0.83 ha); Nong Son (0.09 ha).
- When the sea level rises 80 cm, the area of agricultural land likely to be flooded is 637.07 ha. In particular, ranked from high to low districts/cities with land areas likely to be flooded as follows: Nui Thanh (191.39 ha); Tam Ky City (157.13 ha); Duy Xuyen (110.60 ha); Thang Binh (72.89 ha); Dien Ban (63.46 ha); Que Son (26.62 ha); Hoi An City (11.75 ha); Phu Ninh (2.88 ha); Nong Son (0.36 ha).

The agricultural land area likely to be inundated due to sea level rise accounts for a relatively small proportion of the total agricultural land area. However, to avoid losses to agricultural production in Quang Nam, it is still necessary to propose appropriate solutions to suit the flooded area in the future.

### 5.2 Impact of climate change on rice yield in Quang Nam Province

Crop yields in general and rice yield in particular depend on climatic conditions greatly. When having favorable conditions, climate will be the basic factor for the process of growth and development. For sowing period of rice, the appropriate temperature is in the range of 20°C–35°C, the total number of sunny hours is over 700 h. During tilling period, the most suitable temperature is 25°C–32°C, temperatures lower than 16°C and higher than 38°C are not favorable. The flowering and seeding periods require the most suitable temperature is from 28°C–30°C (Thanh *et al.*, 2016).

From the data series of rice yields from 1999–2018 in Quang Nam Province, there were many fluctuations, especially in the winter–spring crop. Although the trend of rice productivity is always increasing due to the application of intensive techniques. But in fact,

winter–spring rice productivity in many years decreased, caused by adverse weather conditions (Statistical Yearbook of Quang Nam Province, 2000-2018).

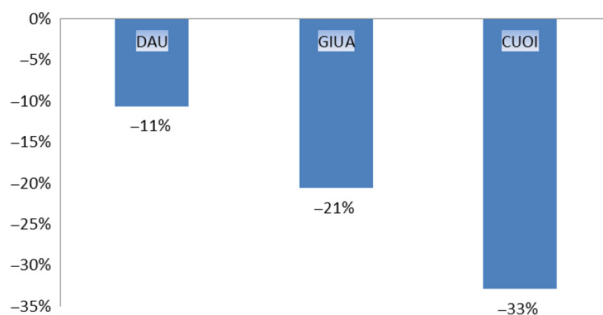
To assess the impact of climate change on the rice yield in Quang Nam Province, the DSSAT model was applied to simulate future rice yield under different climate change scenarios. The climatic factors affecting the rice yield in Quang Nam Province were selected as input data for the DSSAT model include: annual average temperature; average maximum annual temperature; average minimum annual temperature and annual average rainfall under baseline period and climate change scenarios.

To investigate the reliability and the accuracy of the calculated results obtained from the DSSAT model, the following widely used statistical measures were used: mean error (ME), mean absolute error (MAE), root mean square error (RMSE). From the data series of rice yields from 1999-2018, it is revealed that error in rice yield simulation of winter–spring crop is of 0.94 quintals/ha; summer–autumn crop of 0.54 quintals/ha. Thus, it can be confirmed that the model was reliable to assess the impact of climate change on rice yield in Quang Nam Province.

This study calculated yield changes for both winter–spring and summer–autumn rice crops in the whole province, assuming no changes in varieties, caring methods, planting dates, soil, irrigation regimes, but only the climate changes in temperature, rainfall, humidity, sunshine hours due to climate change. Specific results are as follows.

**5.2.1 Winter–spring.** Rice productivity clearly showed a downward trend in periods from the beginning of the century (2016-2035) to the middle of the century (2046-2065) and the end of the century (2080-2099) under the RCP scenario 4.5. At the beginning of the 21st century, the productivity in this area is 11% lower than the baseline period; by the middle of the 21st century, the yield of rice decreased by 21% compared to the baseline period; and, by the end of the 21st century, the rice yield decreased by 33% compared to the baseline period. Thus, over time, rice yields tended to decrease sharply (decreasing by 10% from the beginning of the century compared to the middle of the century and 22% from the beginning of the century to the end of the century) (Figure 2).

**5.2.2 Summer–autumn.** Like winter–spring rice, in Quang Nam, due to the impact of climate change, summer–autumn rice yield shows a downward trend. However, for each period of the RCP4.5 climate change scenario, the increase and decrease of rice yield varies from the beginning of the century (2016-2035), to the middle of the century (2046-2065) and the end of the century (2080-2099). At the beginning of the 21st century, rice yield decreased by 21% compared to the baseline period; by the middle of the 21st century, rice yield decreased by 36% compared to the baseline period; and, by the end of the 21st century, rice



Source: Huynh (2020)

**Figure 2.** Simulation of winter–spring rice yield in Quang Nam under RCP 4.5 scenario compared to the baseline period (1986-2005)

yield decreased by 49% compared to the baseline period. Thus, over time, the summer–autumn grain yield also tends to decrease sharply (down 25% from the beginning of the century compared to the middle of the century and 28% from the beginning of the century to the end of the century compared to the period) (Figure 3).

5.3 Impact of climate change on the water demand for rice

For rice production, irrigation water plays an important role. Water has the effect of regulating the microclimate in the field, facilitating the supply of nutrients, reducing the temperature, salt, alum, toxins and weeds (De, 2008).

Recently, Quang Nam often faces challenges of natural disasters, especially droughts. Under the impact of climate change, water storage in dams and reservoirs may not be able to meet the irrigation level of irrigation stations. It can be said that this is one of the great difficulties in agricultural production in Quang Nam Province.

To determine the impact of climate change on water demand for rice, the study used CROPWAT model to estimate irrigation water demands for rice in the baseline period (1986-2005) and under different climate change scenarios (RCP 4.5 and RCP 8.5).

Similar to the impact of climate change on rice yield assessment, it is necessary to investigate the accuracy of the estimated results of the water demand. However, the data for water demand in the past is not available. For that reason, the authors had to analyze many previous studies on using CROPWAT to calculate the water demand for crop in Viet Nam in general and Quang Nam in particular. The authors found that, CROPWAT was used to the prediction of water requirements for Srepok river, An Giang province, Quang Nam Province, Quang Ngai [...] (Quyên, 2019; Hanh et al., 2012; Huong, 2010; Dung et al., 2014). Given that the extensive use of CROPWAT model in similar conditions, the model can be reliable use to estimate irrigation water demands for rice in the baseline period (1986-2005) and under different climate change scenarios (RCP 4.5 and RCP 8.5) in Quang Nam to assess the impact of climate change.

The results showed that the demand for irrigation water for rice in Quang Nam Province increased differently between the baseline period and under different climate change scenarios (RCP 4.5 and RCP 8.5). Specifically (Table 4):

- With RCP 4.5 scenario, the water demand for rice in Quang Nam Province is 437.23 million m<sup>3</sup> (234.14 million m<sup>3</sup> in winter–spring crop; 203.09 million m<sup>3</sup> in summer–autumn). Water demand increases by 31.1% compared to the baseline period, of which the winter–spring crop increases by 28.4%; the summer–autumn crop increases by 34.3%.

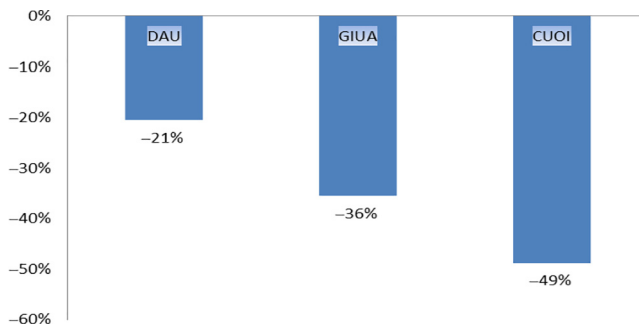


Figure 3. Simulation of summer–autumn rice yield in Quang Nam under RCP 4.5 scenario compared to the baseline period (1986-2005)

Source: Huynh (2020)

District/city	1986–2005			RCP4.5			RCP 8.5		
	Winter– spring	Summer– autumn	Total	Winter– spring	Summer– autumn	Tổng	Winter– spring	Summer– autumn	Total
Thăng Bình	32,85	25,48	58,33	36,28	32,68	68,96	38,68	34,64	73,32
Điện Bàn	20,22	18,42	38,64	26,28	25,29	51,57	28,65	26,48	55,13
Đại Lộc	18,94	17,85	36,79	22,68	21,36	44,04	24,83	28,52	53,35
Duy Xuyên	18,18	14,5	32,68	26,47	24,23	50,7	27,02	25,32	52,34
Quế Sơn	16,3	12,52	28,82	22,13	14,04	36,17	23,16	18,62	41,78
Núi Thành	13,34	12,98	26,32	18,65	16,82	35,47	20,27	18,12	38,39
Phú Ninh	12,12	10,66	22,78	16,12	12,38	28,5	18,14	15,28	33,42
Tiên Phước	10,57	6,44	17,01	14,06	8,26	22,32	16,27	9,34	25,61
Nam Giang	2,46	7,94	10,4	6,28	8,82	15,1	9,15	10,23	19,38
Hiệp Đức	6,32	2,47	8,79	8,82	5,25	14,07	10,24	7,87	18,11
Nông Sơn	7,23	1,46	8,69	8,43	3,66	12,09	9,62	8,17	17,79
Bắc Trà My	4,56	3,39	7,95	6,12	5,23	11,35	8,13	8,25	16,38
Đông Giang	3,65	4,21	7,86	3,09	5,96	9,05	5,54	10,12	15,66
Tam Kỳ	5,2	2,48	7,68	4,38	4,48	8,86	6,43	6,29	12,72
Tây Giang	2,57	3,96	6,53	3,29	4,97	8,26	5,76	5,69	11,45
Nam Trà My	2,63	3,18	5,81	3,68	4,25	7,93	5,13	5,98	11,11
Phước Sơn	2,75	1,96	4,71	3,26	2,56	5,82	5,27	4,37	9,64
Hội An	2,48	1,29	3,77	4,12	2,85	6,97	5,26	3,25	8,51
Total	182,37	151,19	333,56	234,14	203,09	437,23	267,55	246,54	514,09

Note: Unit:  $10^6$  m<sup>3</sup>/year

Source: Huynh (2020)

**Table 4.**  
Water demand for  
rice in 2046–2065  
compared to baseline  
period in Quang Nam  
Province

- *With RCP 8.5 scenario*, the water demand for rice in Quang Nam Province is 514.09 million m<sup>3</sup> (267.55 million m<sup>3</sup> in winter–spring crop; 246.54 million m<sup>3</sup> in summer–autumn crop). Water demand increases by 54.1% compared to the baseline period, of which the winter–spring crop increases by 46.7%; the summer–autumn crop increases by 63.1%.

Thang Binh, Dien Ban, Dai Loc, Duy Xuyen, Que Son, Nui Thanh and Phu Ninh are the districts with greater irrigation demand than others. The different of water demand for rice in localities is closely dependent on local water supply capacity, rice cultivation area at the present time and in development plans.

## 6. Conclusion

Climate change has been happening in Quang Nam Province. Simulation results from the DSSAT model show that, rice yield will decrease in both winter–spring and summer–autumn crops under climate change scenario RCP 4.5. By the end of the 21st century, winter–spring rice yield may decrease by 33%, while summer–autumn rice yield may decrease by 49%. In this study, the authors only conducted research on the effects of climate change on rice yield with the assumption that cultivation techniques, fertilizer regimes, intensive level, biotechnology are constant.

The evaluation results revealed the risk of climate change impacts on rice productivity in both seasons (winter–spring and summer–autumn) in Quang Nam, contributing to help Quang Nam Province have a more comprehensive view of agricultural activities in general and rice production in particular in the context of climate change. With quantitative estimates of the impacts of climate change, policymakers will be able to have more suitable

adaptation options in the future, to minimize the potential damage to agriculture caused by climate change.

Water demand for rice in Quang Nam Province is increasing. Under RCP 4.5 scenario, water demand increases by 31.1% compared to that of baseline period, of which the winter–spring crop increases by 28.4%; the summer–autumn crop increases by 34.3%. Under RCP 8.5 scenario, water demand increases by 54.1% compared to the baseline period, of which the winter–spring crop increases by 46.7%; the summer–autumn crop increases by 63.1%. Districts such as Thang Binh, Dien Ban, Dai Loc, Duy Xuyen, Que Son, Nui Thanh and Phu Ninh are the districts that have greater irrigation demand than other districts in both the baseline period and the climate change scenarios (RCP 4.5 and RCP 8.5). Increased demand for irrigation water is resulted from the area of the rice production and the expected drought increase in the future under the climate change scenario.

The area of agricultural land likely to be flooded in 2020 is 19,889.5 ha (accounting for 12.2% of the provincial agricultural land area), in 2050 is 20,303.9 ha (accounting for 12.5% of the agricultural land area). The province's industrial area is 21,402.4 ha in 2100 (accounting for 15.6% of the province's agricultural land area). The area of agricultural land likely to be inundated increased by 28% (2020); 31% (2050); 63% (2100). The area of inundation from 0–1 m is the largest amongst various levels of flooding compared to 1999. The area of agricultural land likely to be inundated by sea level rise at 50 cm is 418.32 ha; at 80 cm it is 637.07 ha. Such an inundated agricultural land area will be considered a significant disadvantage for the agricultural sector in the future.

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### Further reading

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