Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of European Agrarian Diplomacy

Master's Thesis

Impacts of climate change on agriculture in Vietnam

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Thesis title

Impacts of climate change on agriculture in Vietnam

Objectives of thesis

The main objective of the study is to clarify the impact of the climate change on agricultural production(AP). then there propose solution to cope with the impact of climate change on agricultural production.
to achieve this goal, the thesis sets 3 tasks
+ systematize theoretical issues on climate change and its impact on AP
+ analyzing the current status of the impacts of climate change on AP
+ proposing solutions to cope with the impacts of climate change on AP

Methodology

+ methods of collecting, synthesizing documents and processing information

+ statistical methods, analysis and comparison

+ map and chart method

The proposed extent of the thesis

60 pages

Keywords

climate change, Vietnam, agriculture, food security

Recommended information sources

Adger, W. N. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. World development, 27(2), 249-269.

Arndt, C., Tarp, F., & Thurlow, J. (2015). The economic costs of climate change: a multi-sector impact assessment for Vietnam. Sustainability, 7(4), 4131-4145.

Balica, S., Dinh, Q., Popescu, I., Vo, T. Q., & Pham, D. Q. (2014). Flood impact in the Mekong delta, Vietnam. Journal of Maps, 10(2), 257-268.

Bangalore, M., Smith, A., & Veldkamp, T. (2019). Exposure to floods, climate change, and poverty in Vietnam. Economics of Disasters and Climate Change, 3(1), 79-99.

Barker, R. (2004). Macro policies and investment priorities for irrigated agriculture in Vietnam (Vol. 6). Iwmi.

Blankespoor, B., Dasgupta, S., & Laplante, B. (2012). Sea-level rise and coastal wetlands: impacts and costs. World Bank Policy Research Working Paper, (6277).

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Declaration

I declare that I have worked on my master's thesis titled "The Impacts of Climate Change on Agriculture in Vietnam" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis. I declare that the thesis does not break any copyrights.

In Prague on 29th of March 2022

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Pham Thi Thu

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I would like to thank doc.Ing.Petr Procházka, MSc, Ph.D., for him advice and support during my work on this thesis.

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IMPACTS OF CLIMATE CHANGE ON AGRICULTURE IN VIETNAM

Abstract

This study intended to explore how climate change affects agriculture in some specific areas of agricultural production, including the assessment of the possibility of agricultural land loss and the impact of climate change on rice productivity. This research project applied the method of collecting statistical data, approaches of processing, analyzing, comparing and evaluating; the method of systemizing geographic information using mathematical models; and the methods resulting from professional solutions. The evaluation of the results indicated that due to the sea level rise, the area of agricultural land that is inundated at 35cm is 517.12ha, and at 60cm is 614,85ha. Based on the representative concentration pathway (RCP) 5.0 scenario and the data of the baseline period, the water demand slightly increased with 24.2% while this number is higher with 26.3% under the RCP 8.5 scenario. Therefore, the productivity of the winter-spring rice harvest has decreased by 12% compared with the number of the summer-autumn crop[1]. Some solutions for adaptation were suggested to mitigate the impacts of climate change on agriculture. It is necessary to consider the application of technological and scientific solutions into the agriculture in the region to improve the situation. Besides, the local authorities and policymakers should formulate and implement appropriate plans for long-term and short term benefits.

Key words: climate change, Vietnam, agriculture, food security

[1] DASGUPTA, S., LAPLANTE, B., MEISNER, C., WHEELER, D., & YAN, J. *The impact of sea level rise on developing countries: a comparative analysis*. 2009, p. 381.

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Abbreviations

AP	Agricultural production
MONRE	Ministry of Natural Resources and Environment
IPSL	Institute Pierre-Simon Laplace
GISS	Goddard Institute for Space Studies
UNEP	United Nations Environment Programme
UN	United Nation

1. Introduction

Climate change has affected most regions around the world, which resulted in serious perturbation to the natural systems. Vietnam was among the countries that were mostly influenced by climate change (WB; 2010[2]; ISPONRE, 2009[3])[4], particularly the coastline and delta regions. While the increase in temperature has affected significantly every aspect of the residents' daily life in the country, the unstable rainfall fluctuations and the increased weather extremes has posed considerable threats to various agricultural sectors in Vietnam. These phenomena left a trail of massive destruction on the agricultural activities and production. In other words, because agriculture plays a significant role in the economic development in the country and it is still the primary source of income for most households in rural areas, climate change has left a serious problem in the region. This paper proposed some metrics that help to quantify special impacts of climate change on some agricultural aspects such as the rice productivity or the agricultural land loss. In addition, the assessment of climate change and the findings were formed with qualitative parameters to provide a general look at the influences caused to the country. In general, the study of the impacts on agriculture will help to clarify the perception of the problem caused by climate change, then it may quantify the impacts and help to formulate the plans to respond timely to the issues.

[2] WORLD BANK. *The Social Dimensions of Adaptation to Climate Change in Vietnam*. Discussion Paper number 17, World Bank. 2010.
[3] ISPONRE. *Viet Nam Environment and Climate Change Assessment.* 2009.
[4] DASGUPTA, S., LAPLANTE, B., MURRAY, S., & WHEELER, D. *Exposure of developing countries to sea-level rise and storm surges*. 2009, p. 571.

2. Objectives and Methodology

2.1 Objectives

The main objective of the study is to clarify the impacts of climate change on agricultural production (AP), and the paper will propose some solutions to cope with this problem.

To achieve this goal, the thesis will focus on three main tasks. Firstly, it will systemize theoretical issues on climate change and its impacts on the AP. Secondly, it will analyze the current status of the problem. Lastly, the thesis will propose possible solutions to deal with the effects of climate change on the AP.

2.2 Methodology

The basic approach which helps to outline this research paper is the mixed methods. By combining the qualitative and quantitative aspects of the data analysis, the paper will offer a general look at the impacts of climate change on the AP as well as generally evaluate the effectiveness of current strategies applied to deal with the problems. The implementation of mixed methods in scientific research projects can satisfy the requirements of a multidisciplinary enterprise which requests for a diverse and extensive array of reliable methods. The researcher has a chance to understand the research questions as well as identify the outcome of the research finding by reviewing the data source of sampling and research methodology. The next step is to combine relevant techniques or specific tools which serve a distinctive methodological aspect. The choice of appropriate tool and an effective amalgamation can result in an informative discussion which can facilitate further projects in the future.

Most of the data will be collected, synthesized, and processed based on the theories and techniques of the Ricardian approach, which allows the researcher to estimate the impacts precisely and offer a logical look at the influences resulting in the AP. Besides, the thesis also applies a wide variety of statistical methods to analyze, compare, and evaluate the data. With all the information collected during the research procedure, some approaches using map and chart models will be employed to illustrate and describe the numbers sufficiently.

The sampling group of data will be collected in six different provinces, mainly in the center and the south of the country, including Quang Binh, Ha Nam, Nghe An, Long An, Vinh Long, and Dong Thap. The information and data will be picked based on the focus of the paper on agricultural land loss and the productivity of rice production. Because of differences in the weather condition, geographic features and other natural factors (e.g. the soil type, slopes, vegetation, drainage patterns, surface water, flood plains, etc.), relevant strategies and models will be chosen to measure and collect the data.

The size of the sampling group: the data collected in different provinces will focus on mainly the neighborhoods of the six provinces, while minor factors (e.g. the temperature, the amount of rainwater, the soil types, etc.) can represent special features in the regions. The amount of subjects can be a useful source for the researcher in case he wants to conduct more than one type of study.

Without much expenditure of time and energy, the statistics as well as the data report can be collected easily due to the support from the local government and partly from the local residents. Besides, there is equipment included during the research projects to collect precise measurements and increase the validity and reliability of the information collected. Due to the relatively huge source of information obtained during the project, it is necessary to apply relevant approaches to analyze the information.

a) Internal validity

This definition will extend the relationship between the starting line of the project and the expected or possibility of the finding. With appropriate data analysis, the research project can confirm its explanation and discussion ideas in a constructive and meaningful way. Because the figures and data collected in a wide area, with typical features in the neighborhood, the possibility to collect the information as well as conduct the qualitative research (e.g. interview/ survey) or apply a mixed method is not within the boundary.

b) External Validity

The application of research findings and discussion ideas can be a good reference for further projects. When conducting the project, it is necessary to pay attention to minor details such as geographic features or natural characteristics that can affect the results. Additionally, the researcher can focus on the type of data (e.g. the speed of erosion, the

drainage patterns, the infrastructures in the region, etc.) and the method used to analyze the information collected. The diversity of the samples as well as the size of the sample group is also noticed to ensure the accuracy and reliability of the final results. If the researcher just approaches the statistics in just a few places of the province, the conclusion drawn after that cannot be reliable. The enlargement of the year range and level should be considered.

If the research is conducted applying the cluster random sampling process, it can be very risky to come to any conclusion. Due to the fact that most of the research is quantitative in nature, they may follow a deductive approach to the generation of knowledge using highly structured procedures and measuring instruments. Even if all the data collected can be taken into consideration, any evaluation which accounts for the overall impacts is not entitled to be announced. In other words, the samples that are gathered in one place cannot be the main representative for the whole region and all the features in other provinces.

3. Literature Review

3.1. Geographic features of the country

With more than 17.7 million of people employed in the sector, agriculture plays the key roles in the country's economic development, which accounted for 33.06% of the total employment in Vietnam. Together with forestry and fishing, agriculture accounted for 14.85% of the total GDP in 2020.

With specific geographic features, Vietnam has specific requirements for agricultural development. The country covers an area of 333,698km^2, which stretches from 8035'N to 23022'N (approximately 15 latitudes). The climate and seasons vary depending on the locations, which are split into three particular zones, including the northern areas (subtropical humid climate), central and south-central regions (tropical monsoon climate), and the southern zones (tropical savannah). Therefore, the seasons and changes in weather also vary from this place to another place. For example, there are four distinguished seasons in the north while it is dry, hot, and rainy in the south. Besides, because of the long coastline stretching from the South China Sea to the Gulf of Tonkin, the effects of the sea

and ocean can be observed in coastal provinces from the north to the south. The annual amount of rainfall water is measured between 1,200mm to 3,000mm.

The country's terrain also differed in various regions. The north of Vietnam includes mountainous and hilly areas, with a wide range of highland areas and green jungle while the delta neighborhood is flooded seasonally and the weather changes gradually in seasons. The Southern region is dominated with an estuary of river systems, known as Mekong River, which results in a low, flat, and fairly marshy part of the country. The main features of this area are recorded with rich soil with frequent tropical rain. The central and south central regions between Ho Chi Minh City and Vinh city are filled with low-lying rain forests and upland forest. Along the country, the Annamite Mountain chain covers a wide area, which is the reason for the mountainous weather in many different provinces.

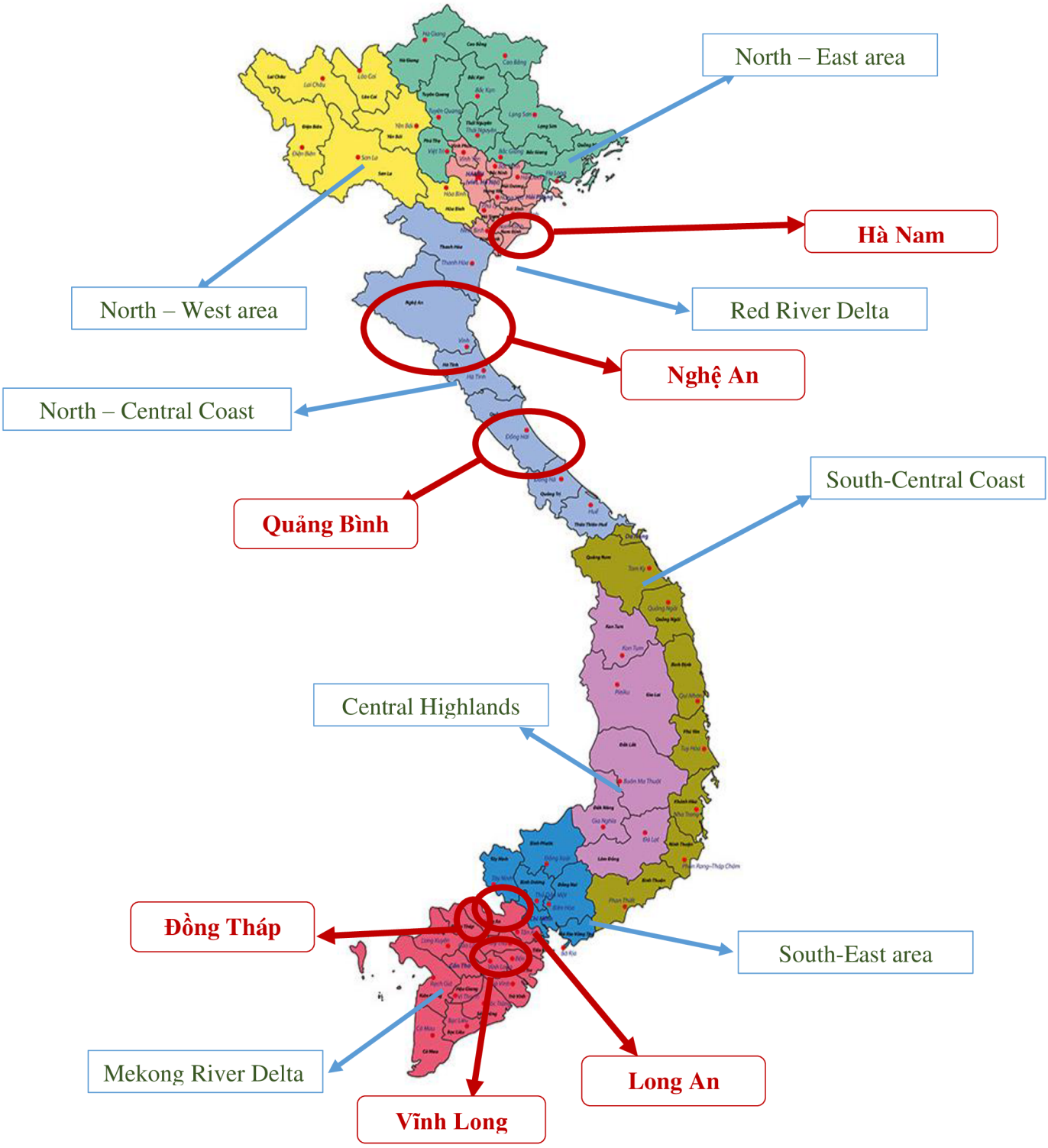

Figure 1 Map in Vietnam

(source: IMHEN)

Despite the fact that Vietnam is a tropical monsoon country in general, the climate and temperature are varied in different zones. The North of the country has four distinguished seasons with a hot rainy summer, lasting for nearly 4 months with very high humidity, and the cold, dry season with fairly low temperature overnight. On the contrary, the south of the country always experiences a tropical climate with high average temperature, while the center climate is mainly affected by coastal influences.

Besides, special characteristics of the society also affect agricultural activities. According to the Vietnam General Statistics Office in 2021, the country's population exceeded the number of 97.6 million people. The Red River Delta and coastal plains in the lowland areas are intensively populated by rice fields, which is covered with a populated network of dikes and levees. Based on the characteristics of the climate and the regional topography, the country is split into eight distinguished agro-ecological areas, including the North West, the North East, The Red River Delta (in the North of the country), the North Central Coast, the South Central Coast, The Central Highlands (in the center of Vietnam), the South East and the Mekong River Delta (in the South). With these regional categories, the agricultural activity and production line have different specialized aspects and fields. While the two delta areas (e.g. the Red River Delta and the Mekong River Delta) focused on rice production, especially the Mekong delta is among the great rice-producing regions in the world, the Central areas (e.g. the Central Highlands and the South East) concentrates mainly on the cash crops. Other regions in the north of the country (e.g. the North East and the North West) only try to satisfy the households' needs. Random neighborhoods where the lowland is arable can be in favor of industrial crops (e.g. tea, coffee, rubber). The central areas also have agricultural activities along the coast.

Agriculture in Vietnam mainly focuses on rice production, which is cultivated in most arable land (about 94%). Both of the delta areas can provide nearly 43 million tons of rice and occupy nearly 80% of the national rice-planted areas. Although other crops can be found along the country (e.g. maize, fruit trees, perennial industrial plants, cassava, pepper, etc.), Vietnam is known as the 5th rice-producing and the 2nd rice-exporting country in the world.

Table 1 A review of main geographic features of Vietnam

A Review of main geographic features of Vietnam	
Country Location	South East Asia
Total Area	331,210km^2 + Land: 310,070km^2 + Water Area: 21,140 km^2 + Boundary Line: 4,639km^2
Irrigated Land	45,850km^2
Coastline	3,444 km
Population	97,34 million (~18 million in Agriculture)

(Source: Wikipedia)

3.2. Regional features of the six provinces

Quang Binh is located in the north central coast with the topography of slopes, higher in the west areas. This region is mostly mountainous with narrow plains and some river deltas. The land is sandy (accounting for 5.9% of the total area) due to the long coastline (116.04km). The province has a large area covered with forests (approximately 4,867 km2), including the natural jungle and reforestation. With seven main river systems originating in the Truong Son Range, moving to the sea, the province has a total 160 lakes (both natural and manmade), providing 234,3 fresh water to the neighborhood. Besides,

there are special continental shelf, economic areas, sea deep-water port, and industrial parks.

There are four different seasons in the region. During the season with warm and slight rains, it is humid while it can be really hot and dry with random downpours in the summer. When the temperature goes down in the fall, it becomes rainy and cooler but turns to humid with slight rain in the winter. Specific features of the weather result in the distinguished agricultural activities and cultivation calendar in the province.

The main focus of the province's agriculture is the production of commodities. The crops and harvest time are arranged based on the climate. While the total amount of food production has been gradually increasing in the last decade, the number of areas for industrial trees dominantly occupies the total land. In the period between 1996 to 2000, the agriculture growth rate is 5.7% and the fishery sector is also developing at a very fast speed[5]. Over the last ten years, Quang Binh has been considered as a model due to the breakthrough in shifting its traditional agriculture to sustainable commodity-oriented production.

The local government and authority also launched multiple programs to develop rural areas, focusing on rice field re-zoning and developing related infrastructures (e.g. roads accessing the fields, improvement of the dykes and dams, upgrading irrigation networks, mechanized production lines, etc.). Besides, there are large areas used to pilot new large-scale field models to increase the quality and productivity of agricultural activities, particularly the rice production. The plan to merge small fields in communes has restructured the crops whereas the shift from traditional crops to new production zones with fruits and industrial plants. The promotion of scientific and technology-applied techniques in farming models has helped the province achieve several positive results[6]. The use of high-quality rice varieties and crop diversification was carried out. In pilot areas, the experimental model of ST25 rice farming crops enabled the potential to shorten the growth duration (up to 4 months), particularly in the summer –autumn crop (about 100 days) and improve the resistance to pests and diseases. More investment in scientific

[5] SCHMIDT-THOME, P., NGUYEN, T. H., PHAM, T. L., JARVA, J., & NUOTTIMÄKI, K. Climate change in Vietnam. In *Climate change adaptation measures in Vietnam*. 2015, p. 13.
[6] NGUYEN, C. T., & SCRIMGEOUR, F. '*Measuring the impact of climate change on agriculture in Vietnam: A panel Ricardian analysis'*. 2022, p. 42.

research and experiments contributed to the improvement of rice production as well as increased the quality and value of the product.

Ha Nam is a province with the plain located in the south of the Red River. Lying in the Red River Delta, the region is bordered with mountains. There is the depth and density of the dissected topography and rock mountains in the area. The dense system of rivers in the east is a big advantage which results in fertile soil and lucrative source of fresh water appropriate for wet rice cultivation, fisheries and industrial crops[7].

The climate of the province represents all features of the tropical monsoon characteristics. Ha Nam has a typical tropical climate with two separate seasons (rainy and dry seasons) and mild temperature (around 23^0C). The amount of rainfall is high with 1,900mm and the humidity is up to 85%, changing randomly depending on the areas. With a long dry season (from November to April), the cultivation calendar is slightly different from neighboring provinces in the same neighborhood[8].

The main exported agricultural products are rice and baby melon, potatoes, and flowers. Currently, the province is planning to have more modernized projects with technological advances to restructure their agricultural activities and rural areas. New cultivating crops are encouraged including the flowers, fresh and safe vegetables, mushroom farming[9]. Advanced farming techniques are considered to be applied in utilizing agricultural waste, high-tech floriculture, and livestock clusters. Besides, the implementation of biotechnology in farming with bio-fertilizer is focused to obtain high yield and good quality products[10].

Nghe An is the largest province in the country, which is located in the North Central Coast area in Vietnam's map. The total land area is mainly covered with the forest and mountains (83% natural area is hilly and mountainous lands), belonging to the North East of Truong

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[7] NGUYEN, T. H., LE, H. T., VO, N. Q. T., DUONG, N. M., NGUYEN, D. L. & NGUYEN, K. L. *Assessing the impacts of climate change on water resources in the Srepok watershed, Central Highland of Vietnam.* 2017, p. 529.

[8] HUONG, N. T. L., BO, Y. S., & FAHAD, S. *Farmers' perception, awareness and adaptation to climate change: evidence from northwest Vietnam.* 2017, p.5.

[9] GEBRETSADIK, Y., FANT, C., & STRZEPEK, K. *Impact of climate change on irrigation, crops and hydropower in Vietnam (No. 2012/79)*. 2012, p.9.

[10] ISIK, M., & DEVADOSS, S. *An analysis of the impact of climate change on crop yields and yield variability.*2006, p. 537.

Son Range[11]. This is the neighborhood with complicated topography, including a wide range of hills, mountains, rivers, etc. The terrain is dissected by the dense river system and the long coastline.

The climate is the tropical monsoon or tropical wet and dry, which is mainly affected by the seasonal winds (in four months). With this type of savanna climate, the average temperature is relatively mild (around 23-24^{0}C). There are two distinct seasons: the rainy and the dry season[12]. The long hours of sunshine in the region is a potential advantage for agriculture development with multiple crops and harvests.

Due to special geographic features of the province, Nghe An can develop different economic aspects such as tourism, forestry, fisheries, etc. other than merely focusing on wet rice cultivation and farming[13]. Although agriculture does not play a key role in the economy in the area, there is a gradual development in agricultural activities. The food production increased up to 1.2 million tons in 2014 while agriculture, forestry and fishery continue to grow stably. The total production of farming and exploiting aquaculture increased 10.52%.

Located in an advantageous position, ***Long An*** is among the provinces belonging to the Southern Key Economic Region of the country in the Mekong River Delta. The level of the fields in the regions is silted by Vam Co Dong and Vam Co Tay river, which is a bonus for agriculture development of the province[14]. The terrain of Long An is fairly flat in general, except for some neighborhoods in the north.

Long An has typical subtropics and monsoon climate with the rainy season lasting for 6 months. The average temperature is high (about 27-29^{0}C) all year round. The humidity is high while the daylight is long[15]. With the low-lying coastal terrain and a complicated network of rivers and canals, some neighborhoods may be affected by the seasonal floods

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[11] LAUX, P., NGUYEN, P. N. B., CULLMANN, J., & KUNSTMANN, H. Impacts of land-use/land-cover change and climate change on the regional climate in the central Vietnam. In *Land Use and Climate Change Interactions in Central Vietnam.* 2017, p. 147.

[12] RUTTEN, M., VAN DIJK, M., VAN ROOIJ, W., & HILDERINK, H. *Land use dynamics, climate change, and food security in Vietnam: a global-to-local modeling approach. 2014, p.32.*

[13] LE, T. D. P., VO, D., VU, H., & HUYNH, T. D. X. *Estimating the economic impacts of climate change on crop production in coastal provinces of the Mekong delta Vietnam.* 2015.

[14] SEBESVARI, Z., LE, T. T. H., & RENAUD, F. G. Climate change adaptation and agrichemicals in the Mekong Delta, Vietnam. In *Environmental change and agricultural sustainability in the Mekong Delta*. 2011, p. 223.

[15] HANH, P. T. T., & FURUKAWA, M. *Impact of sea level rise on coastal zone of Vietnam.* 2007, p. 45.

in rainy seasons[16]. According to a report by Can Tho University (2009)[17], about 49% of the province's land will be flooded once the sea level increases 1 meter in the future.

With the tendency of the economic mechanism as the agriculture-industry-service integration, Long An can take advantage of its fertile soil and water resources. There are four types of soil characters, diversifying from alluvial, gray soil to acid sulfate and saline soil[18]. The different groups of classifications resulted in the differences in the features of the botanical ecologies in the area.

Agricultural areas in the province put their focus on producing rice and agricultural products (e.g. sugar cane, peanuts, pineapples, dragon fruits, etc.). Rice is the major product of the province's agriculture with 2.6 million tons a year, making the province the biggest granaries in Vietnam[19]. Due to the diversity of natural conditions, farming methods can apply different techniques and cultivate many kinds of rice (e.g. the high yield common varieties)[20]. There are specialized communes and villages for rice production (e.g. Kien Tuong town), including several rice types such as high-yield rice varieties, local and sticky rice, etc.

The local government also plans to develop the economy of the province in multiple dimensions. Currently, Long An is encouraging the development of industrial parks, with more than 10,216 ha of the total land converted to industrial land)[21]. Agricultural activities can also be diversified with fruit trees and vegetables while the development of services and industries are effectively supported by helpful policies and projects.

Vinh Long lies in the center of the Mekong Delta River, between two big rivers, Hau and Tien river. Like most other neighboring provinces in the farming hub, Vinh Long has the tropical monsoon climate with two distinct seasons: rainy and dry period (each lasts for nearly 6 months. The rainfall is high (1,650mm a year) and the sunshine hours are long (10

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[16] THAO, N. D., TAKAGI, H., & ESTEBAN, M. *Coastal disasters and climate change in Vietnam: Engineering and planning perspectives.* 2014, p. 2.
[17] DASGUPTA, S., LAPLANTE, B., MEISNER, C., WHEELER, D., & YAN, J. *The impact of sea level rise on developing countries: a comparative analysis.* 2009, p. 384.
[18] KHOI, D. N., SAM, T. T., LOI, P. T., HUNG, B. V., & NGUYEN, V. T. *Impact of climate change on hydro-meteorological drought over the Be River Basin, Vietnam.* 2021, p. 3161.
[19] KHOI, D. N., & SUETSUGI, T. *Hydrologic response to climate change: a case study for the Be River Catchment, Vietnam*. 2012, pp. 218.
[20] BANGALORE, M., SMITH, A., & VELDKAMP, T. *Exposure to floods, climate change, and poverty in Vietnam.* 2019, p.87
[21] SCHMIDT-THOME, P., NGUYEN, T. H., PHAM, T. L., JARVA, J., & NUOTTIMÄKI, K. Climate change in Vietnam. In *Climate change adaptation measures in Vietnam*. 2014, p. 9-10.

hours a day) (Waibel, 2008). The humidity range varied from 79%-86%, depending on the season in the year whereas the temperature ranged from 26 to 28 ^{0}C. The terrain of the region is quite flat with a complex network of rivers and canals[22]. The soil characteristics are special, which is rich in alluvium. This is the reason for the province's preference for rice and fruit cultivation.

Due to the complete irrigation and the good network of dike systems, the flood and drought were partly controlled while fresh water suppliers were fulfilled all year round. Besides, Vinh Long is also rich in clay and sand natural resources due to the contribution of big rivers and the long coastline (Viet, 2011). With the fertile soil, mild climate, the sediment of the rivers, Vinh Long is an ideal condition to grow rice, exotic types of fruits, and different tropical crops were grown in the neighborhood. This province is also famous for fisheries with a wide range of farm fish and freshwater aquatic species (e.g. prawn, catfish, etc.). By restructuring the sector and the emphasis on product quality, in 2018, the target for agricultural production was more than USD 23 million. Despite the effort to improve the quality and productivity of rice, the land area for rice cultivation was reduced by nearly 20,000 ha. The main focus of the economy shifted from rice to fruit trees, fish farming, cattle and poultry breeding.

Dong Thap's topography is quite flat due to its location in the Mekong Delta region. Lying in the tropical climate zone, there are two separate seasons with the average rainfall up to 2,000mm. the average temperature ranges from 21 to 35oc. Special features of the hydrology are affected by the flood water from Mekong River, the in-field rain water, and the tides from the sea.

With a sloping tendency, the province is naturally split into two parts. The neighborhood benefits from the Tien river and its dense network of channels, spring system. The silt-aggraded soil together with fresh and non-saline freshwater resources are advantages for agricultural development, especially rice cultivation. The annual rice and seafood output and export of Dong Thap made the province one of the top performers who achieved a fair economic growth rate.

[22] HUONG, N. T. L., YAO, S., & FAHAD, S. *Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam*. 2019, p1168.

With the plans for sustainable agriculture, focusing on rice production, Dong Thap encouraged the restructuring models to a higher added value and sustainability. By transforming from a traditional small scale model to a commodity-based production method, the agricultural activities in the region have applied modern scientific techniques and advanced technology processes into practice. This means the levels of automation are effectively enhanced while the mindset is gradually changed. The cost of product and household income have changed due to the increase in productivity of the farming output. Apart from rice, other crops such as fruits or fish farming are also a strong point in the local economic development plan.

Table 2 Regional features of the six provinces

	Quang Binh	**Ha Nam**	**Nghe An**	**Long An**	**Vinh Long**	**Dong Thap**
Total Area	8,065 km^2	860,2km^2	16,490km^2	4,493km^2	1,520 km^2	3,283km^2
Population	857,820 (2008)	787, 000 (2010)	3.1 million (2010)	1.45 million (2010)	1,1 million	1,6 million (2019)
Agricultural land	1,636km^2	45,000hectares	276.047 hectares	450,000ha	119.900ha	26,730km^2
Special features	4,876 km^2 of forests Agriculture growth rate: 5.7%	Large rivers	Long coastline (82km^2)		Big rivers	

(Source: Wikipedia)

3.3. Impacts of climate change in agricultural activities in the past.

From 2014, natural disasters and extreme weather increased rapidly, affecting agricultural production in different ways. Strong storms and lightning broke or damaged the irrigation works and the network of dike systems, leading to the crop devastation in the southern provinces. The severe cold weather with several episodes of cold air resulted in remarkable damages to newly planted rice and rice paddles in the northern and Red River Delta. Different locations in the Central-North and Central-South areas suffered from the drought and flash floods.

The change in temperature varied in different areas but generally caused the increase in the average annual temperature, indirectly causing drought, salinity, and other related issues. Following are the statistics of the slight change in temperature in different regions throughout the country predicted based on different scenarios, including the IPSL, GISS, and MONRE in two years of 2030 and 2050.

Table 3 The slight change in temperature in different regions throughout the country 2020 and 2030

Name of the Regions	**IPSL**		**GISS**		**MONRE**	
	2030	2050	2030	2050	2030	2050
North-West Area	1.18	2.22	0.91	1.39	0.80	1.33
North East Area	1.18	2.22	0.89	1.41	0.73	1.28
Delta Areas in the North	1.19	2.21	0.87	1.42	0.70	1.28
North-Central Area	1.14	2.02	0.85	1.41	0.85	1.55
South-Central Area	0.86	1.61	0.99	1.62	0.53	0.93

Name of the Regions	IPSL		GISS		MONRE	
	2030	2050	2030	2050	2030	2050
Central Highland Neighborhood	0.84	1.57	0.94	1.55	0.50	0.85
South East Regions	0.81	1.49	0.78	1.30	0.63	1.03
Mekong Delta	0.84	1.54	0.78	1.31	0.62	1.02

(Source: Wikipedia)

It can be concluded that the temperature was predicted to increase gradually and reached the highest point in most areas in 20 years. The northern areas will have much higher temperature increase compared with the one in the south and Mekong River Delta.

Modernized irrigation systems in the regions, which could provide a stable and reliable supply of fresh water for farming in particular, and agricultural activities in general, have not met the increasing demands for extreme drought seasons in recent years. This resulted in serious impacts on the farming calendar, especially in areas where wet water cultivation is the main crop.

The changes in the amount of rainfall water varied from the north to the south. While the downpours happened regularly in the North-West, the Red River Delta got a larger amount of water from streams and rivers. The random rains in the summer in the South could not satisfy the requirements for rainwater in the dry seasons. In the Central Highlands, the amount of rainwater dropped significantly to 5% each year (from 2016-2018). This was one of reasons for a long dry season in provinces who do not have a long coastline or have a higher location than the sea level[23].

[23] TRAN, T., NGUYEN, V. T., HUYNH, T. L. H., MAI, V. K., NGUYEN, X. H. & DOAN, H. P. *Climate change and sea level rise scenarios for Vietnam. Ministry of Natural resources and Environment.* 2016, p.9.

Similarly, the loss of rice-growing land and rice production areas in the delta river also has changed in the next few decades. Specifically, the Mekong River Delta, due to the flood inundation and salinity intrusion in the next 30 years, will have at least 276 ha of affected neighborhood during the rainy season and double this number in the dry season[24]. When the sea level changes, the change in the amount of yield land will range from 5 to 6 tons per hectare. The loss in rice production and productivity is predicted to drop from 1 to nearly 2 million tons every year, accounting for 5-8% of the total rice production in the neighborhood[25].

In 2018, there were 13 storms and tropical depressions, which seriously affected agricultural activities throughout the country, especially in provinces specializing in wet rice cultivation. More than 212 thunderstorms and tornadoes of lightning together with 14 flash floods and landslides resulted in the land loss in provinces with a long coastline. About 9 strong winds on the sea which bring about bad weather to the coastal neighborhood[26]. In the north of the country, particularly the Red River Delta and the North West basin, there were four cold spells and damaging cold, 23 episodes of cold air, causing serious damage to the spring-summer harvest calendar. In the Central and the Central-South of the country, it was recorded with 11 heat waves in the summer. Meanwhile, the south of Vietnam, including the Mekong River Delta and the coastal areas, suffered from 30 heavy rains on a large scale with major floods originating from big rivers in the regions. The spring tide and the river bank erosion has caused a loss in economic and the local workforce[27].

The impacts in crop productivity were observed in most provinces, regardless of their geographic locations and other natural features. The rice yield declined in most scenarios, ranging from 4.2% to 12.5%[28]. The decline taking place in the Central Highlands and the North-West was more serious than other neighborhoods, which seriously affected the food supply and the food security in the areas. In delta regions, including both the Red River

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[24] LE, T. B., & SHARIF, H. O. *Modeling the projected changes of river flow in central Vietnam under different climate change scenarios.* 2015, p. 3582.
[25] DASGUPTA, S., LAPLANTE, B., MEISNER, C., WHEELER, D., & YAN, J. *The impact of sea level rise on developing countries: a comparative analysis.* 2011, p. 380
[26] TRINH, L. T., VU, G. N. H., VAN DER STEEN, P., & LENS, P. N. *Climate change adaptation indicators to assess wastewater management and reuse options in the Mekong Delta, Vietnam.* 2013, p. 1184.
[27] DAS GUPTA, M. *Population, poverty, and climate change.* 2014, p. 92.
[28] HO, T. T., & SHIMADA, K. *The impact of climate change adaptation response on rice farmers' livelihood in Soc Trang province of Vietnam*. 2018, p. 21.

Delta and the Mekong River Delta, the influences of climate change were relatively moderate, ranging from 1.4 to 8.3%, but this slight change also affected major rice-producing regions negatively. The total amount of rice productivity in Long An and Vinh Long reduced gradually from 0.2% to 3.5% every year (from 2015 to 2017).

Due to the changes in the sea levels, many natural and geographic features in different provinces were affected. In 2 years (from 2016-2018), the sea level increased 12 mm every year, whereas this number is predicted to go up to 17 cm in 2030 and 30 cm in 2050. With the rising sea level scenario throughout the country, most provinces close to the sea or have a long coastline witnessed a change in their climate characteristics. For example, in the Mekong River Delta, the flood inundation situation rose up to 30 cm, even with the installation and equipment with hydraulic structures and the improvement of the infrastructures. Moreover, the areas inundated with water extended sharply with a deeper level (around 50 cm) while the total amount of agricultural land loss increased up to 276 thousand hectares. This number was increasing, particularly in the rainy seasons when there was floods or flash floods in the regions[29]. During the dry seasons, because the amount of the rainfall water was limited, the salinity intrusion, especially with intense concentration (about 4 grams per liter of water), was significantly enlarged with more than 400 thousand hectares. This number varied when calculating the total area of agricultural lands, including the paddy rice areas. Only in three provinces in the Mekong River Delta (Long An, Vinh Long, and Dong Thap), the areas specializing on wet rice cultivation, which were affected by the inundation, were 193,000 ha, whereas the salinity intrusion caused the loss of 294 thousand ha. As a result, the loss in agricultural land, especially the rice area, led to the decline of the rice production and food productivity in the whole neighborhood[30]. The rice yields in 2017 witnessed a decrease of 2,7 million tons, due to the inundation (with 900 thousand tons declined) and salinity intrusions (with 1.8 million tons decreased). The figures in the year accounted for nearly 13 percent of the total rice harvest amount in the Mekong River Delta[31]. Similar results could be observed and recorded in different places, including the Central-South basins and Highland

[29] BLANKESPOOR, B., DASGUPTA, S., & LAPLANTE, B. *Sea-level rise and coastal wetlands: impacts and costs.* 2012, p. 6277.
[30] STORCH, H., & DOWNES, N. K. *A scenario-based approach to assess Ho Chi Minh City's urban development strategies against the impact of climate change.* 2011, p. 519.
[31] KAWASAKI, J., & HERATH, S. *Impact assessment of climate change on rice production in Khon Kaen province, Thailand.* 2011, p. 19.

neighborhoods, despite the loss of land was not as serious as the southern provinces if measured due to their total areas.

The increased level of the sea also led to significant impacts in agricultural activities, especially in provinces with the long coastline. Among the six provinces (Nghe An, Ha Nam, Quang Binh, Long An, Vinh Long, and Dong Thap), there are five of six locations with the climate features affected mainly by the oceanic climate. This influence resulted in changes not only in the harvesting calendar as well as the related agricultural activities[32]. Most neighborhoods, except for the delta areas in Ha Nam and southern sectors, considered replacing the wet rice cultivation with the growth of fruit trees or the development of fisheries. Besides, the farming habits and methods also changed to adapt to the new circumstances. While some provinces applied new farming techniques and with a wide range of rice varieties to increase or maintain the amount of rice productivity, the other converted agricultural lands into industrial areas (e.g. Vinh Long). Most locations along the country supported or encouraged scientific projects to figure out appropriate methods and agricultural models for their regions.

The amount of rice yields estimated by province fluctuated from year to year and slightly depended on the geographical features. Despite the disparities in the productivity of rice production in various regions, the common tendency among provinces was the declination of the amount of products. Although the application of modernized technology and advanced farming methods, the total amount of rice production in the Southern areas declined gradually (from 1-3.4% per year) in 3 years (2015-2018). This change could be observed in the Central Highlands neighborhood as well as the North East regions[33]. With the alarming drop in the seasonal and potential crop yield, the effects of climate change were not among the main concerns, which could attract more attention from the community.

Since 2018, climate change has made the demand for fresh water suppliers unexpectedly increase. The water supply capacity due to the success of irrigation works was much lower than the real expectation from the local farming activities. The lack of water for agriculture not only damages the crop but also the loss in the economy. In addition, the change in the

[32] STORCH, H., DOWNES, N., KATZSCHNER, L., & THINH, N. X. Building resilience to climate change through adaptive land use planning in Ho Chi Minh City, Vietnam. In *Resilient cities*. 2011, p. 358.
[33] BALICA, S., DINH, Q., POPESCU, I., VO, T. Q., & PHAM, D. Q. *Flood impact in the Mekong delta, Vietnam.* 2014, p. 261.

total amount of rainfall has led to the unstable water distribution to the yield and paddle, which indirectly affects the quality and the productivity of the rice harvest[34]. In some regions of the Central provinces (e.g. Quang Binh, Nghe An, Ha Tinh, etc.), the unseasonal heavy rains caused flash floods and drought, leading to the inundation of rice and farming activities. In the southern areas such as Long An, Vinh Long, or Dong Thap, the saline intrusion into the interior created a shortage of fresh water and led to the lack of agricultural land and negatively influenced the food security for the country. Moreover, when the sea level rose, the areas covered with saline soils in the delta regions increased, causing the flood in different neighborhoods[35].

The loss of farmland and agricultural land significantly has declined the crop yields and posed a threat to the rice exports as well as the food security in the last 10 years. Due to the crop patterns being changed, the rice productivity plummeted sharply while there was a record of epidemics in farming activities[36]. It is predicted that the yield of the spring crop will dramatically decrease by 0.41 tons per hectare in 2030, double this number in the next 20 years.

Moreover, most natural disasters intensified their powers in a negative way. While the typhoon and seasonal flood lasted much longer than expected (from 20 to 30 days), the droughts in some areas higher than the sea level became more vulnerable to aridity and caused severe damages to crops and agricultural activities in the neighborhood[37]. The average temperature in the whole country has increased considerably (at least 0.7^0C in the last 10 years), accounting for longer dry seasons, and a hotter temperature in some particular regions which were mainly affected by the monsoon tropical climate[38]. The increasing numbers of heavy rainfall and flooding incidents were a part of natural disaster damages recorded in the period of five years (from 2015 to 2020), whereas random storms, hurricanes, and oceanic climate impacts could be tracked along the coastlines. In the last

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[34] BRUUN, O., & CASSE, T. Climate change, adaptation and the environment in central vietnam. In *On the Frontiers of Climate and Environmental Change*. 2013, pp. 8.
[35] BUI, Hong Long. & TRAN, Van Chung. *Preliminary studies on the impact of climate change on the upwelling phenomenon in south central Vietnam waters in summer.* 2017, p. 6.
[36] HO, T. T., & SHIMADA, K. *The effects of multiple climate change responses on economic performance of rice farms: Evidence from the Mekong Delta of Vietnam.* 2021, p. 128129.
[37] VAN DIJK, M., HILDERINK, M., VAN ROOIJ, H., RUTTEN, M. M., ASHTON, R., KARTIKASARI, K., & LAN, V. C. *Land-use change, food security and climate change in Vietnam: A global-to-local modelling approach.* 2013.
[38] HO, T. T., & SHIMADA, K. *The effects of climate smart agriculture and climate change adaptation on the technical efficiency of rice farming—an empirical study in the Mekong Delta of Vietnam.* 2019, p. 99.

three decades, since the 1950s, more than 200 typhoons have affected and caused damage to many coastal provinces throughout Vietnam despite their weak power and small size[39]. The time when the typhoon occurred became unpredictable and most of them took place at a later time than they used to. The direction of the typhoons also changed, moving down and got closer to the Southern latitude, especially the Southwest areas, randomly at the Eastern Sea[40]. This means more provinces with the long coastline exposed more to typhoons and had a higher frequency of being damaged by their powers.

In 2019, the heatwaves accompanied with the drought occurred in the country many times in the year, which reduced the productivity of the crops and rice production to more than 30%. The spring crop was seriously affected with the rice yield decreased sharply by 3.7% in the Red River Delta while the rice-growing land may reduce to 11%. Provinces with long coastline were affected severely by the salinity which caused a loss of agricultural land area[41]. According to the calculations and forecasts of the Institute of Agricultural Environment, by 2100, the sea level will increase 100cm, and the Mekong Delta may lose 89,473ha of agricultural land and about 7.6 million tons of rice per year[42].

Minor effects of climate change were also recorded in many provinces along the country. The heavy rains resulted in damages of infrastructures, pumping costs, and led to other series of natural disasters such as landslides, flash floods, etc.[43] The rise of the sea level caused floods to the Mekong River Delta, Red River basins, and other coastal provinces, etc. The rainfall was much more concentrated and the wet seasons became wetter and more humid[44]. The precipitation decreased gradually in the Central Highlands and regions with the long coastline, including many provinces in the central south areas. On the contrary, the increase of the temperature together with the evapotranspiration affected the water storage, catchments, random heat waves, drought, and forest fires.

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[39] MENDELSOHN, R., NORDHAUS, W. D., & SHAW, D. *The impact of global warming on agriculture: a Ricardian analysis.* 1994, p. 756.
[40] DANG, A. T., KUMAR, L., & REID, M. *Modelling the potential impacts of climate change on rice cultivation in Mekong Delta, Vietnam.* 2020, p. 9608.
[41] LE, T. T. *Effects of climate change on rice yield and rice market in Vietnam.* 2016, p. 376.
[42] GIANG, P. Q., TOSHIKI, K., KUNIKANE, S., & SAKATA, M. *Integrated water resources management in Vietnam under the challenges of climate change.* 2012, p. 32.
[43] TRINH, T. Q., RAÑOLA JR, R. F., CAMACHO, L. D., & SIMELTON, E. *Determinants of farmers' adaptation to climate change in agricultural production in the central region of Vietnam.* 2018, p. 227.
[44] NGO-DUC, T. Climate change in the coastal regions of Vietnam. In *Coastal disasters and climate change in Vietnam*. 2014, pp. 177.

3.4. Special strategies and implementation activities in response to Climate changes

The country's government has taken a wide variety of aggressive actions, from practical plans to active programs, to deal with the situations. Most of the projects have different concentrations but mainly focus on two different categories: the governmental policies applied to the country and single or particular tasks for each location.

At the national level, there are projects addressing general issues related to marine areas, water resources, rural development, or disaster risk management. The priorities of these plans are supposed to conduct research, share information, raise public awareness, build up capacity, and precisely assess the vulnerability of the community[45]. Specifically, Vietnam has actively worked with programs in cooperation with the global communities by signing several international treaties and commitments. Besides, the country also participates in a series of action programs to cope with the effects of climate change.

Approved under the Prime Minister's Decision No. 158/28/QD-TTg, signed on December 2, 2008, the National Target program on Responding to Climate Change is a forefront policy which shows the lever for adaptation to environmental changes. This approval was considered as the first step to raise awareness in the community by formulating a development framework with legal mechanisms and documents[46]. Besides, it is also the initial stage to improve and enhance the national capacity to cope with impacts of climate change in different aspects and sectors. The policy also designed feasible and practical action plans for short and long-term benefits, including the aims for sustainable economic development.

The National Strategy on Climate Change was approved by the Prime Minister in 2011, focusing on specific objectives. The first concentration was on the issues related to action plans ensuring food security, reducing poverty, promoting gender equality, protecting water security, taking care of the community's health, improving the standard of living, and preserving natural resources. The second aim of the strategy mentioned the efforts for developing a sustainable economy and maintaining a green economic growth. The third term in the plan presented the importance of raising public awareness and community

[45] YU, B., ZHU, T., BREISINGER, C., & HAI, N. M. *Impacts of climate change on agriculture and policy options for adaptation: The Case of Vietnam* (No. 1015). 2010, p. 8.
[46] VIEN, T. D. *Climate change and its impact on agriculture in Vietnam.* 2011, p. 19.

responsibility for dealing with climate change influences[47]. This objective is also concerned with the support for sustainable and eco-friendly methods to improve and change the consumption habits and lifestyles. The last aim highlighted the fundamental cooperation with the international community in response to impacts of climate change in the regions. The policy also emphasized the role and duty of the National Committee on Climate Change towards providing the Prime Minister and governmental bodies with advice for strategic solutions. It is essential for this organization to propose projects which aims at the mobilization and coordination of resources. Because most of the members of the Committee are among the country's leaders (e.g. the Prime Minister, the Deputy Prime Minister, the Minister of Natural Resources and Environment, scientists, experts, and representatives from the National Assembly agencies and research institutes, etc.), the committee is among the main institutional bodies who could be in charge of monitoring crucial and extensive policies concerning with the changes of environmental conditions. The main mission initially included the development of legal laws and bills related to climate change policies. Besides, appropriate mechanisms were discussed to adapt to specific development stages, which helped Vietnam keep up with the international conventions and global tendency.

The National Action Plan on Climate Change, which set up the targets to implement the National Strategy on Climate Change in the period of 8 years (from 2012 to 2020), was issued in 2012. It listed more than 65 multiple programs, plans, and projects to support and regulate the starting time when the implementation was launched and the agencies who would be responsible for the activities. An important task of this committee was to determine the foundation and the basis to develop and issue laws concerning climate change problems.

The National Strategy for Environmental Protection (2012-2030), managed by the Ministry of Natural Resources and Environment, was approved in September, 2012. Its main objective of the action plan was to primarily control and limit the pollution, resource depletion, and biodiversity degradation. The long-term goal was to prevent and reverse climate change effects, proactively support the capacity to respond to greenhouse effects, and improve the standard of living, especially the quality of the living environment. The strategy also suggested main directions for the protection of the environment, consisting

[47] DUNG, N. H. *How severe is the impact of climate change on crop production in the Mekong Delta-Vietnam?*. 2012, p. 97.

of the focus on the prevention and management of pollution sources, the rehabilitation and restoration of degraded areas, the improvement of fresh water supply and sanitation services, the sustainability use of natural resources, the conservation of nature and biodiversity, the capacity to respond to climate change, the reduction of greenhouse gas emission, etc. This plan provided a comprehensive reference to protect the environment at different levels and in different sectors, which boosted the success of the implementing procedure of sustainable development objectives.

The Green Growth Strategy was approved under the Decision No. 1393/QD-TTg, signed in September 2012 by the Prime Minister. This action plan mentioned three important goals. First of all, it emphasized the restructure and improvement of the economic institution with the strategies of greening all existing sectors and fields. The development of important economic regions should be encouraged while the use of energy and resources should be managed effectively, intending to add higher value to the development of the economy. Secondly, it is necessary to support the application of advanced technologies and research projects to use natural resources sufficiently and reduce the intensive impacts of greenhouse effects. These activities could be a valuable help for the sustainability greenhouse gas reduction plan. The strategy also clearly addressed the amount of greenhouse gas reduction in each period of time (e.g. from 2011 to 2020 is 8-10%, and 2020-2030 is 2% each year). The last objective that the strategy presented was the improvement of residents' standard of living, changes in daily habits and lifestyles, the investment in natural capital, the support for the development of the green industry, sustainable agriculture, infrastructure and services.

In 2013, the Resolution 24 was issued by the Party Central Committee, which focused on strengthening the integrated sustainability and capacity to respond to climate change in the country. This resolution also gave a sample model for green growth that facilitated businesses and organizations who wanted to support and invest more in sustainable development[48]. There was a legal framework which accompanied this resolution to design special policies to support the development of the economy and businesses.

A year later, in 2014, the Law on Environmental Protection was revised and approved. This was a chance to show a strong legal commitment by the government to the environmental protection and climate change impacts. Specifically, this law promoted

[48] TRAN, N. L. D., RAÑOLA, R. F., SANDER, B. O., REINER, W., NGUYEN, D. T., & NONG, N. K. N. *Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam.* 2019.

activities that helped to protect the environment and deal with climate change. Besides, it added some special chapters that accompany the mission to protect the environment with socio-economic development programs, the management of greenhouse gas emission and ozone depleting substances[49]. The law also pointed out the importance of clean and renewable energy, eco-friendly production line and consumption market, the recycling of waste, and the contribution and responsibilities of the community in protecting the environment[50]. The development and implementation of scientific methods and advanced technology as well as the mutual cooperation with the international community was also discussed in detail in the law chapters.

The implementation plan of the Paris Agreement was developed and approved in October 2016 by the Government of Vietnam showed the determination of the country to respond to impacts of climate change. The content of the plan mentioned 5 important tasks, including the minimization of greenhouse gas emissions in 15 years (2016-2030), adaptation to the climate change, the effective development of resource use, the system transparency set up and the essential stimulation of amendment of policy institutions in the country[51]. The main objective of this action plan was to present detailed projects to solve the problems that resulted in the impacts of climate change. For example, to reduce pollution factors such as greenhouse gas emission, there were particular goals to achieve. These targets were listed based on the Business as Usual Scenario (BAU) and international assistance[52]. The figure to obtain was 8-25% of greenhouse gas emission reduction in 15 years. To adapt to climate change, Vietnam was committed to programs and projects within the national strategies to improve the resilience, protect people's lives and contribute to the reduction of pollutant use[53].

Moreover, the Vietnam Institute of Meteorology, Hydrology and Climate Change in cooperation with the Embassy of Denmark have sponsored and worked on the project focusing on the benefits of the development in rural areas and the adaptation to climate change based on the models of small and medium-sized hydropower plants in 3 years

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[49] ARNDT, C., TARP, F., & THURLOW, J. *The economic costs of climate change: a multi-sector impact assessment for Vietnam*. 2015, p. 4137.

[50] ADGER, W. N. *Social vulnerability to climate change and extremes in coastal Vietnam*. 1999, p. 256.

[51] TRI, N. H., ADGER, W. N., & KELLY, P. M. *Natural resource management in mitigating climate impacts: the example of mangrove restoration in Vietnam.* 1998, pp. 52.

[52] NHU, O. L., THUY, N. T. T., WILDERSPIN, I., & COULIER, M. *A preliminary analysis of flood and storm disaster data in Vietnam.* 2011.

[53] LE, T. V. H. , SHIGEKO, H., NGUYEN, H. N., & TRAN, T. C. *Infrastructure effects on floods in the Mekong River Delta in Vietnam.* 2008, p. 1363.

(2006-2009). There were two main objectives recorded in the project[54]. Firstly, it would provide a thorough understanding of the benefits which small or medium-scale hydropower plants can offer to adapt to climate change and develop the rural areas. Secondly, the project proposed some effective mitigation methods and measures to alleviate and minimize the influences of those plants' activities and models on the environment and the local community, especially poor groups in the regions[55].

The Adaptation Support to Climate Change program, approved and managed by the Ministry of Natural Resources and Environment, was designed to support activities and policies connected with the solutions to climate change effects[56]. With the encouragement from Japan and France, the framework of the National Target Program was implemented and applied to develop different areas throughout the country.

The Ministry of Agriculture and Rural Development, with the support from the World Bank, approved and conducted the Adaptation Support to Climate Change program in 6 years (2011-2017). The main objective of this project was to preserve and protect the water resources, specifically in Mekong Delta provinces[57]. This action plan intended to stabilize the agricultural production line in the regions and support the households and local community to access the clean water supplies and natural freshwater resources[58].

The Nordic Development Fund targeting the National Target Program on Climate Change project was sponsored by the ADB and the Ministry of Industry and Trade between 2011 and 2013. The government of Vietnam and the Fund Nordic Development put their priority focus on urban development and transportation. Ho Chi Minh city, Da Nang, and Thanh Hoa were the piloted locations in the project[59]. The main objective was to enable the country to implement the National Target Program in big cities and apply measures to deal with climate change effectively.

A delegated cooperation between Australia, Germany, and the five provinces (An Giang, Ca Mau, Bac Lieu, Soc Trang, and Kien Giang) resulted in the Climate Change and Coastal

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[54] VAN, H. L., & YABE, M. *Impact of Environmental Factors on Profit Efficiency of Rice Production: A Study in Vietnam-s Red River 2012,* p. 333.

[55] LE DANG, H., LI, E., NUBERG, I., & BRUWER, J. *Farmers' perceived risks of climate change and influencing factors: A study in the Mekong Delta, Vietnam.* 2014, p. 334.

[56] TRAN, T. U., & KAJISA, K. *The impact of green revolution on rice production in Vietnam.* 2006, p. 177.

[57] HO, T. D., KUWORNU, J. K., & TSUSAKA, T. W. *Factors influencing smallholder rice farmers' vulnerability to climate change and variability in the Mekong Delta Region of Vietnam.* 2022, p. 289.

[58] TRINH, T. A. *The impact of climate change on agriculture: findings from households in Vietnam.* 2018, p. 902.

[59] NGUYEN, K. D., ANCEV, T., & RANDALL, A. *Evidence of climatic change in Vietnam: Some implications for agricultural production. 2019, p. 527.*

Ecosystems Program, which lasted 5 years (2011-2016). The primary goal of the program was to help the local government to manage and protect the ecosystems and coastal biodiversity from climate change effects[60].

Besides, there are a large number of projects conducted by the government, NGOs, the Center for Sustainable Rural Development, the Ministry of Natural Resources and Environment, etc. These activities are varied due to the local authorities' viewpoints and individual needs in each province. For example, the three provinces (Can Tho, Binh Thuan, Binh Dinh) expected to focus the public attention, raise their awareness, build capacity, integrate the issues into their local socioeconomic development programs, and look for solutions to the climate change impacts[61]. Therefore, the cooperation with the Ministry of Natural Resources and Environment and the Ministry of Agriculture and Rural Development is necessary for strengthening the national capacity, reducing vulnerability of the local community, and controlling the levels of greenhouse gas emission[62].

Together with the action programs undertaken at the national level, Vietnam also focuses on the commitments and strategies by participating in international activities and projects. For example, between 1995 and 2013, the country actively participated in annual Associations of the Conference of Parties to the United Nations Framework Convention on Climate Change[63]. Some specialized organizations and actions plans in the regions and around the world can be mentioned are the Asian Disaster Preparedness Center, The Association of Southeast Asian Nations Disaster Management Committee, the Asian Disaster Reduction Center, the Natural Disaster Mitigation Partnership, etc.

The Mangroves for the Future, a project supported by the Government of India, Indonesia, Sri Lanka, Pakistan, Maldives, Seychelles, Thailand, and Vietnam, had the main objective to develop the sustainable coastal areas. It also promoted the efforts and called for investment in the neighborhood to protect the coastal ecosystem[64]

From 2009 to 2011, Vietnam was among the most active members of the Community-Based Adaptation Program, launched by UNDP. Working with 9 other members in the

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[60] YU, B., ZHU, T., BREISINGER, C., & NGUYEN, M. H. *Impacts of climate change on agriculture and policy options for adaptation: The Case of Vietnam* (No. 1015). 2010.

[61] HOANG, V. *Impact of Contract Farming on Farmers' Income in the Food Value Chain: A Theoretical Analysis and Empirical Study in Vietnam.* 2021, p. 797.

[62] NGOC, V. B., HUNG, N. M., & PHAM, P. T. *Agricultural Restructure Policy in Vietnam and Practical Application for Sustainable Development in Agriculture.* 2021, p.3.

[63] TRUONG, T. S., DAO, N. K., NGUYEN, T. T. T., PHAM, T. T. N., NGUYEN, T. Q., NGUYEN, X. H. & NGUYEN, V. T. *Impact of climate change on meteorological, hydrological and agricultural droughts in the Lower Mekong River Basin: a case study of the Srepok Basin, Vietnam.* 2019, p. 549.

[64] BARKER, R. *Macro policies and investment priorities for irrigated agriculture in Vietnam*. 2004, p7.

program, Vietnam proactively encouraged and enhanced the adaptability of communities who were affected by climate change[65].

The expansion of the irrigation systems helped to deal with the variability of the climate as well as encourage the adaptation and flexibility of the agriculture in the country. The Central areas of Vietnam had planned numerous projects for irrigation solutions while the number of irrigation increased sharply in the Mekong River Delta. Together with the projects for irrigation systems in the future, it is necessary to improve and enhance the productivity of current irrigated lands to satisfy the demand for food by the local population and other export activities[66]. The estimate of household irrigation intensity positively affected the average yield, particularly in low income neighborhoods such as the Central Highlands or South East areas. Specifically, if the intensity doubles the numbers, the yield increased at least 3 percent although this number was not correct in delta zones.

By cooperating with China, Ecuador, Fiji, Indonesia, Mongolia, Nepal, and the Philippines, Vietnam became an active participant in an international project, namely The Cities and Climate Change Initiative project, funded by the Norwegian government and controlled by the UNEP and UN-Habitat. The main objective of the project was to promote the conversations about policies, develop tools and undertake pilot activities in big cities of the participating countries (e.g. Esmeraldas of Ecuador, Kampala of Uganda, Maputo of Mozambique, Sorsogon of the Philippines). Besides, the project also provides helpful advice to support areas at risk and offers solutions to improve and develop national plans, as well as assess the vulnerability of regions based on the impacts of climate change[67].

Vietnam also actively participated and cooperated in many different other international projects on climate change such as the Cooperative for Assistance and Relief, the International Union for Conservation of Nature, the United Nations Environment Programs, the Asian Cities Climate Change Resilience Network, the Mekong River Commission Climate Change and Adaptation Initiative, the Climate Risk Assessment for Agriculture in Thailand and Vietnam. These are positive signals for the country's sustainable development.

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[65] QUAN, T. T., & WOODFORD, K. B. Agricultural value chains and commercial transition in Quang Binh Province, Vietnam. In *III International Symposium on Improving the Performance of Supply Chains in the Transitional Economies 895*. 2010, p. 231.

[66] VU, D. T., YAMADA, T., & ISHIDAIRA, H. *Assessing the impact of sea level rise due to climate change on seawater intrusion in Mekong Delta, Vietnam.* 2018, p. 1634.

[67] NGUYEN, A. T., TRINH, Q. A., PHAM, V. T., LE, B. B., NGUYEN, D. T., HOANG, Q. N., PHAM, H. T. T., LUU, V. N., HENS, L. *Farmers' intention to climate change adaptation in agriculture in the Red River Delta Biosphere Reserve (Vietnam): a combination of Structural Equation Modeling (SEM) and Protection Motivation Theory (PMT).* 2019, p. 2993.

4. Data Collection and Analysis

During the research projects, there was a slight change in the overall temperatures and those figures also varied in different provinces in the project. In general, the unstable increase is the lowest and highest in the last 7 years. Specifically, the highest temperature seems to get higher with a gradual change, except for the period of 2018-2019, whereas the lowest temperature tends to change sharply, particularly from 2020 to recent time. This increase may vary in different locations but the average temperature also reflects the common tendency of temperature increase, a part of the global warming effects[68].

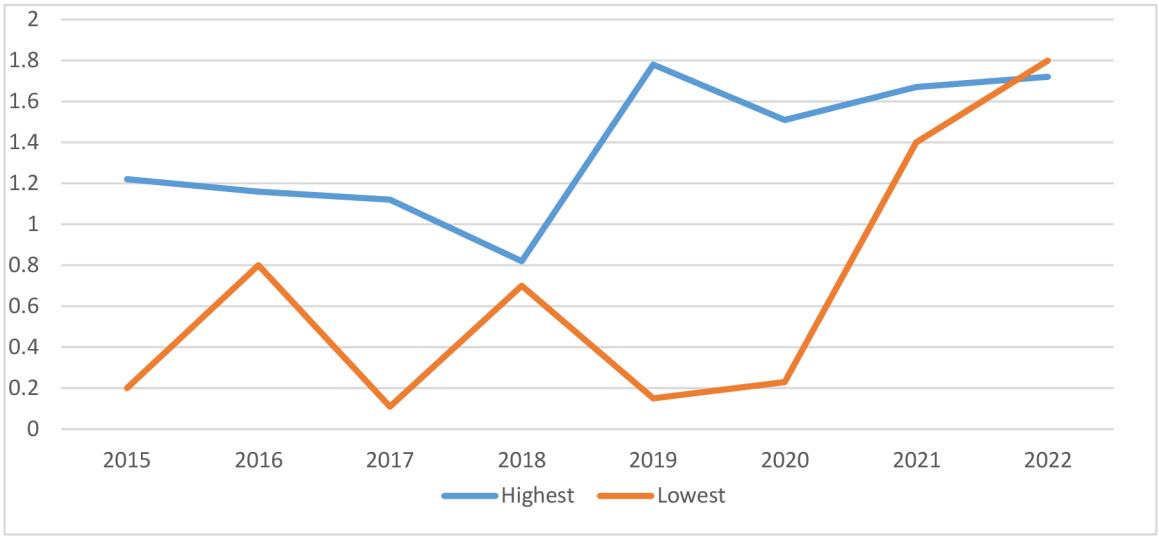

Figure 2. Temperature changes in Vietnam (2015-2022)

(source: Data Collected)

a. Ha Nam

When the data about the temperature was collected in Ha Nam, the change in the below graph also proved the general trend of the whole country. However, the increase in temperature locally took place gradually with a stable speed, recording the hottest month (June-July). However, the average temperature went up slightly (between 20^0C in 2015 and 16^0C in 2022). The unstable change can be reflected through months. In the past, the summer temperature was recorded with an extreme number (39-40^0C), but it has turned to

[68] CLINE, William. *The impact of global warming of agriculture: comment.* 1996, p. 1310.

be cooler in the last six months. While the figures in spring were higher than those in the past, the province has to suffer from colder autumn-winter months.

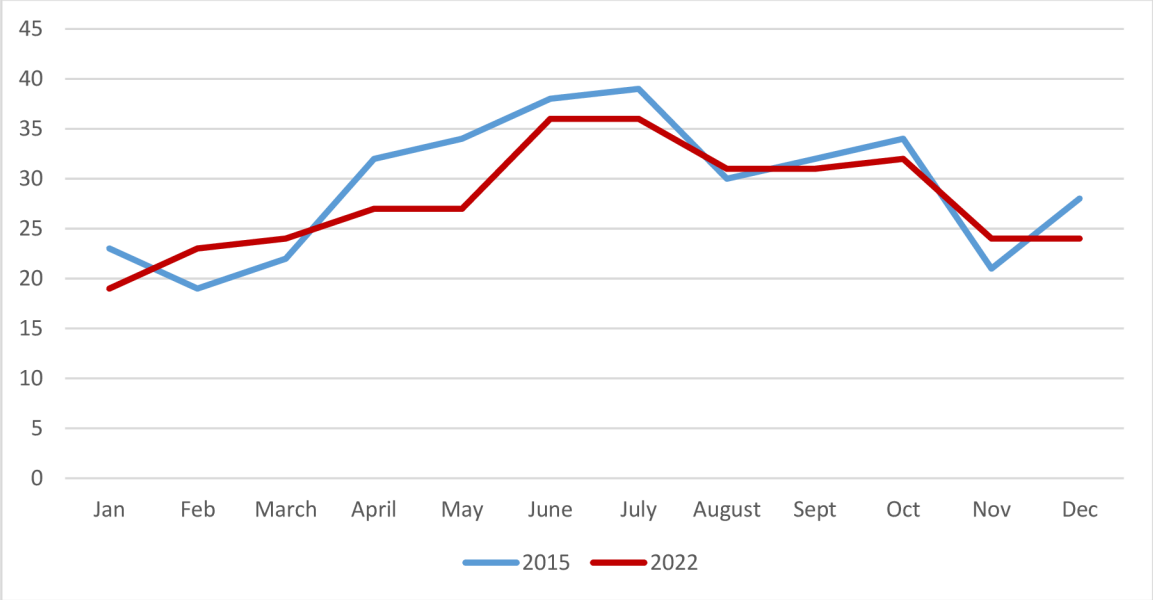

Figure 3 Temperature Variation in Ha Nam from 01/2015 to 12/2021

(source: Data Collected)

There is also a bigger difference in the temperature between the summer and the winter, especially in November. This is also among the reasons resulting in negative impacts in the agricultural activities during this period of time. Not only the Autumn winter crop was affected, the daily routines of local people have to be changed to adapt to colder winter when the temperature drops down sharply (nearly 15^0C in November). The unexpected difference between the hot and dry seasons with the rainy and cold weather also leads to the change in the type of crops grown in the neighborhood (e.g. rice harvest may be converted to fruit or vegetable crops).

The changes in temperatures can be partly predicted based on the total number of daylight hours. As a part of the Red River Delta, which is affected by the tropical monsoon climate and the dissected topography, the longer hours of daylight in Ha Nam can be noted with more than 12 hours of daylight, regardless of the seasons. Despite the slight change in the total figures (between 1 minutes to 10 seconds) in different months in the two years, there is a common tendency found in the following table.

Table 4 Hour of Daylight in Ha Nam

Hours of Daylight in Ha Nam				
	Spring	Summer	Autumn	Winter
2015	12h36'12	12'45'6	12h28'3	12h5'2
2017	12h36'10	12'46'3	12h28'27	12h3'39
2019	12h37'9	12h47'1	12h28'29	12h26'53
2021	12h38'5	12h47'56	12h29'49	12h18'6

(source: Data Collected)

While the daytime lasts longer than expected in the summer, there is a slight change in the total hours of daylight in the autumn and winter. The differences between the summertime and the fall can be observed by the decrease of the daytime hours. This is one of the main factors that can influence the growth rate of the rice fields.

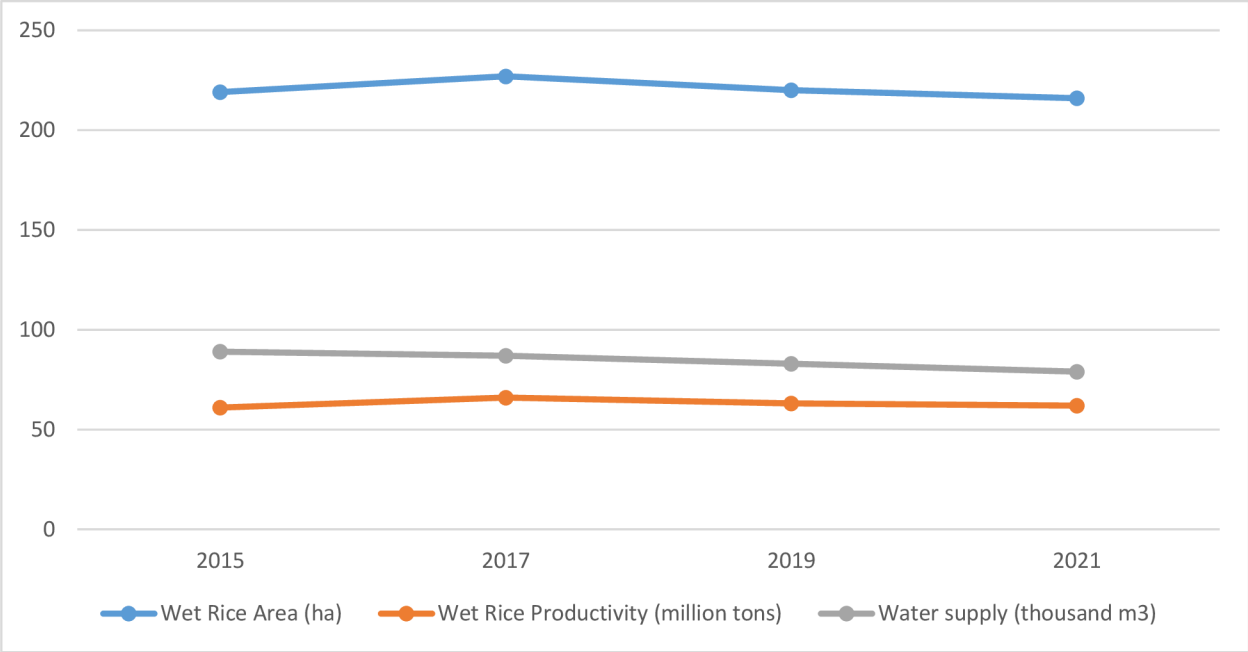

Figure 4 Impacts of Drought over the Red River Delta (source: Data Collected)

In addition, the effects of high temperature in the Red River Delta also resulted in extreme weather and severe drought in the dry seasons. Because Ha Nam is located in the basin, the impacts of droughts can be simply observed through major activities.

The intensity of the droughts and the frequency when they happened can be kept as a good record to explain the decline of rice productivity and other agricultural products. The fast drop of the wet rice area, mainly caused by the shortage of fresh water reserves, led to the wet rice harvest calendar and the crop productivity.

Table 5 The number of land loss in Ha Nam (source: Data Collected)

Numbers of Land Loss in Ha Nam			
Districts	Total Area (km^2)	Land Loss (km^2)	Percentage of Land Loss
Phu Ly	34,2	0,6	1.75%
Thanh Liem	175	1,3	0.7%
Binh Luc	155,5	20,1	12.92%
Duy Tien	135	0,2	0.1%
Ly Nhan	167,1	1,35	0.8%
Kim Bang	184,9	2,8	1.5%

Due to the extreme weather conditions and impacts of climate change, the number of land lost in the last two years was investigated. These results were recorded based on the measurements and calculation of the total area. The largest district is Kim Bang, which has a moderate speed of land loss. Only 1.4% of the total area was lost while this number is much higher in Binh Luc with 12.92%. Although Duy Tien is the district with a smaller land area, the speed of land loss took place gradually with a much smaller area (0,2 km2).

b. ***Quang Binh***

In Quang Binh, the temperature seems to be stable with a similar tendency between 2015 and 2022. The line in both years shows a coincidence in the highest and lowest temperature in the same season. Despite the slight change in the temperature, which has relatively increased in 5 years, the hottest season is in the summer with the peak of May (32oC), while the coldest time is in December (22^0C).

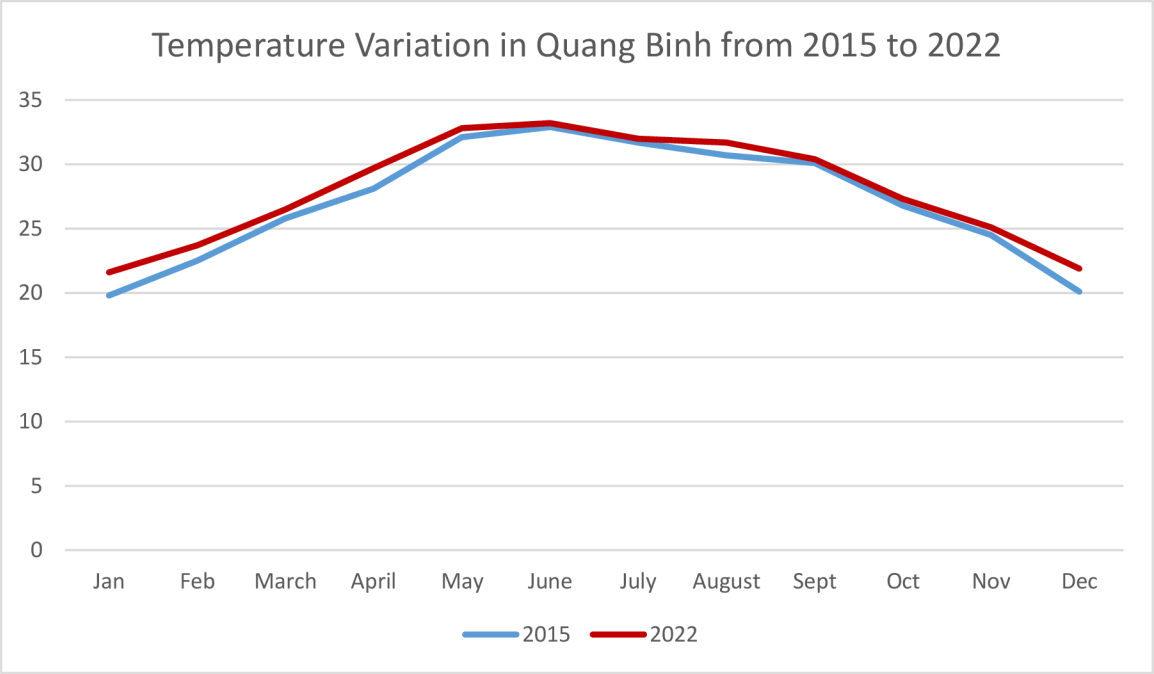

Figure 5 Temperature Variation in Quang Binh from 2015 to 2022 (source: Data Collected)

This tendency may be mutually affected by different climate features such as the humidity, the precipitation, the wind speed, etc. With the long coastline, the coastal influence can significantly improve the increase of temperature increase. Instead, other factors such as the wind speed and direction, the rise of the sea level, etc. may have considerable impacts on the original monsoon climate in the province.

Table 6 Weather in Quang Binh (01/2015-01/2022) (source: Data Collected)

Weather in Quang Binh (01/2015-01/2022)				
	Humidity	Precipitation	Wind Speed	Number of Storms (in high seasons)
01/2015	90%	2%	2,15km/h	15
01/2018	89%	7%	5km/h	21
01/2022	94%	5%	3km/h	37

Both the humidity and the precipitation could change the amount of rainfall water, which can directly affect agricultural activities, especially the rice harvest. While the humidity has increased recently, the precipitation and wind speed seem to decrease slightly due to coastal climate getting closer to the interior areas of the province. Therefore, most of the important activities in the harvest calendar are mainly based on the effects of the climate. Besides, the number of storms tend to go up and their damages as well as related natural disasters (e.g. landslide, flash flood, tornadoes, lightning, etc.) intensified their influences to the local economy.

Table 7 The number of land loss in Quang Binh (source: Data Collected)

Numbers of Land Loss in Quang Binh		
Districts	Total Area (km^2)	Land Loss (km^2)
Ba Don	162	5

Numbers of Land Loss in Quang Binh		
Districts	Total Area (km^2)	Land Loss (km^2)
Le Thuy	1,402	160
Quang Ninh	1,194	204
Bo Trach	2,115	301
Quang Trach	448	12
Tuyen Hoa	1,129	167
Minh Hoa	1,394	118

Among the 9 locations in the province, Quang Trach has the smallest area and the slowest speed of land loss in the neighborhood with 2,67%. Le Thuy is the largest district but the district with the fastest speed of land loss is Quang Ninh (170,81%). The total land loss in Bo Trach is the highest (301 km^2) and smallest area lost was in Ba Don with only 5 km^2.

c. ***Nghe An***

On the contrary, the effects of the weather in Nghe An can be clearly observed with the decline of the precipitation throughout the year. The highest number in September and the lowest in January was maintained but there was a slight decrease in the percentage and random differences in months of the fall and winter.

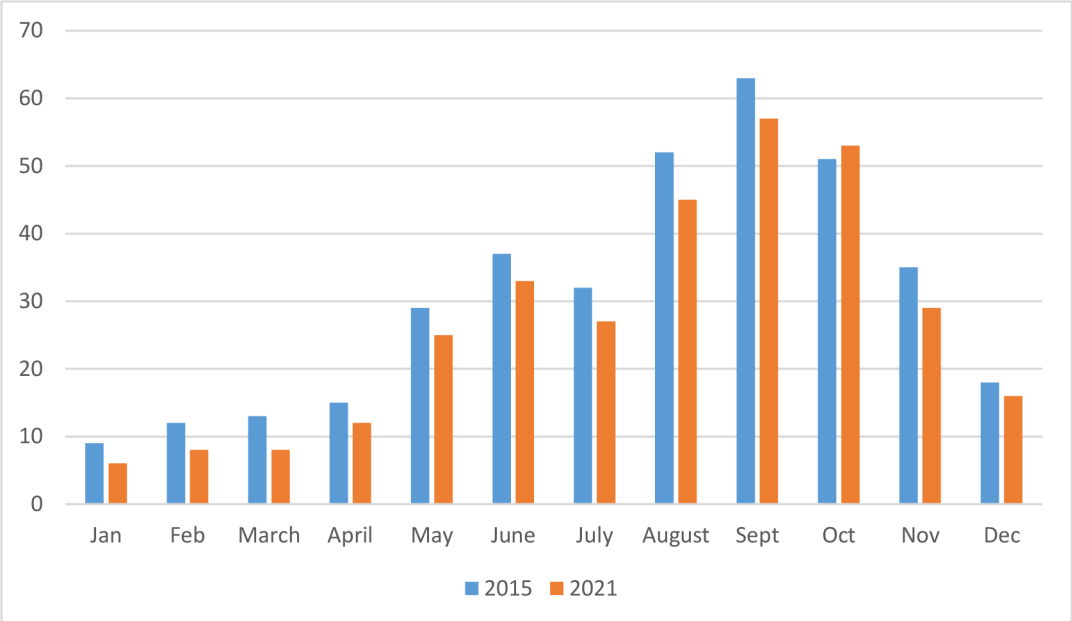

Figure 6Variation of precipitation in Nghe An (01/2015-12/2021) (source: Data Collected)

Due to the slight change in the temperature, the volume and intensity of the heavy rains also gradually fluctuated. The homogeneity tests were applied to calculate the current volume of the rainwater. When comparing the data record throughout the year, it can be noticed that the average amount of rainwater has gradually increased which resulted in severe flooding seasons in the summer or early winter. September is always the month with the highest record while it seems to be dry and hot in springs (in February) and mid-fall time (in August).

Table 8 Average volume of rainwater in Nghe An (source: Data Collected)

Average volume of Rainwater (mm) in Nghe An				
	2015	2017	2019	2021
Jan	2.221	2.317	2.345	2.480
Feb	1.236	1.347	1.521	1.740
March	4.698	4.927	5.413	5.400

Average volume of Rainwater (mm) in Nghe An				
	2015	2017	2019	2021
April	10.427	10.545	10.814	10.950
May	21.969	21.964	22.209	22.540
June	15.023	15.158	15.375	15.570
July	22.514	22.207	22.453	22.720
August	968	1.001	1.045	3.288
September	21.563	21.689	21.698	21.780
October	14.123	14.286	14.504	14.660
November	4.010	4.126	4.267	4.370
December	1.431	1.485	1.576	1.680

Throughout the year, the volume of the rainwater in the province is maintained at a high level compared with the average figure in the region. Even in the early autumn when there are fewer rains, the total amount of rain water is kept above 1,000mm.

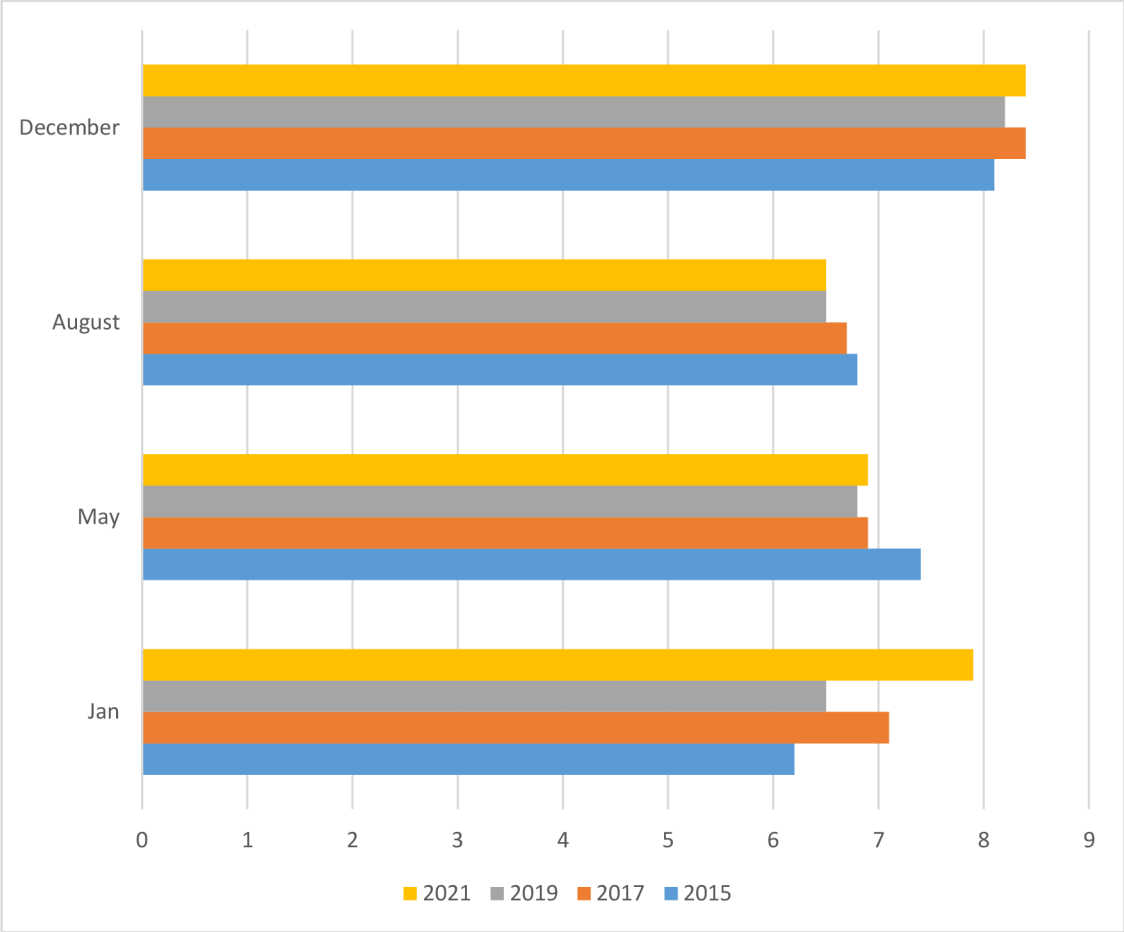

Figure 7 Wind speed in Nghe An (mph) (2015-2021) (source: Data Collected)

While there are heavy rains and random storms in the neighborhood, the wind speed and directions are unstable and tend to be intensified due to various natural and regional factors. Because of the occurrence of the heavy rains and the intensification of the wind in the winter, there are more and more hurricanes and tornadoes in the neighborhood. Moreover, the bars in the chart also present an increasing tendency of the wind speed, which can change the basic characteristics of monsoon climate, and turn the local weather to an unpredictable dimension. This fact does not only affect the agricultural activities and the harvest calendar, but it also changes distinctive features of the climate and other natural factors (e.g. soil components, fertility level of agricultural land, the harvesting habits, the rice varieties chosen for crops, etc.).

Table 1 The number of land loss in Nghe An (source: Data Collected)

Numbers of Land Loss in Nghe An		
Districts	Total Area (km^2)	Land Loss (km^2)
Vinh	105	0.9
Cua Lo	27.81	1.2
Hoang Mai	169.7	10.3
Thai Hoa	135.2	27.1

In spite of the impacts of climate change and the natural process, most districts in the province have had a great effort of protecting their land from disasters (e.g. landslide, flood, etc.). The total land lost because of the natural process is minimized while the effects of climate change are the main elements which caused the loss. Although the lost number of the total areas are not really high, compared with other provinces, necessary methods and agricultural models were applied.

d. ***Mekong River Delta***

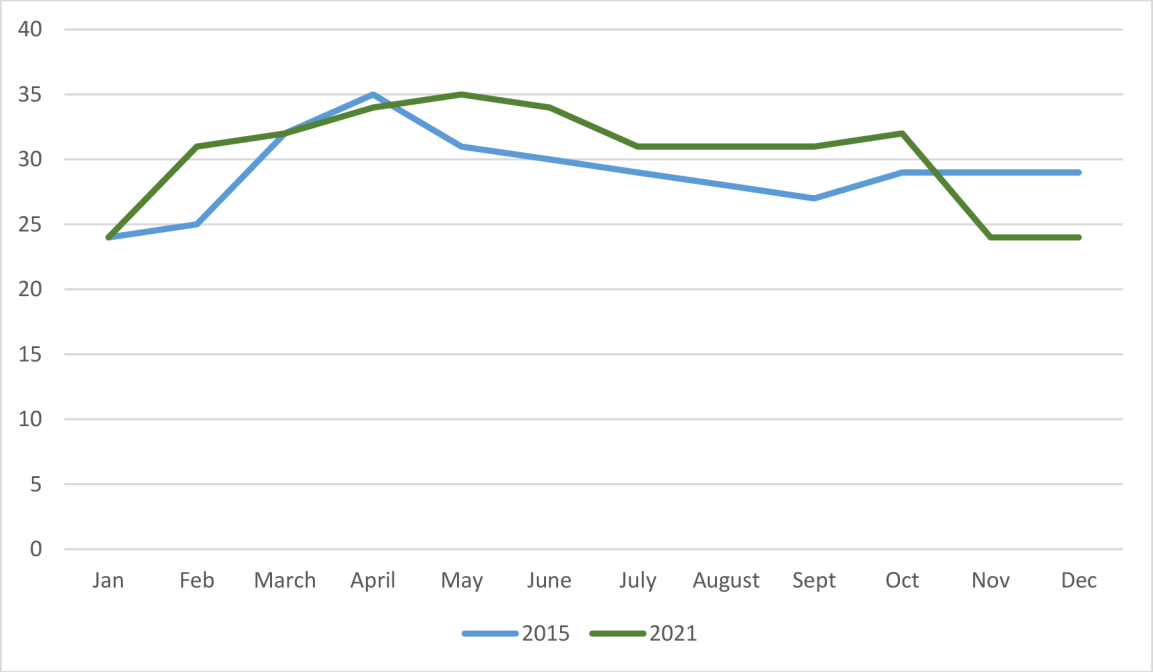

Figure 8 Temperature variation in the Mekong river delta from 01/2015 to 12/2021 (source: Data Collected)

The Mekong Delta River, which is known for mild weather and an advantageous climate for agriculture, especially rice production, also suffered from climate change. Similar to the northern province where the temperature changed a lot, the variation of the temperature in the region is also recorded with a very different result. Firstly, the all-year-round hot and humid weather still keeps its distinguished characteristics with very high temperature due to the local location compared with the equator. While the lines in the graph indicate an increase in the temperature at the beginning and during the year in 2021, the sharp decline at the end of the year proves a change in the climate. From 2015 to earlier this year, the average temperature had never fallen below 25^0C. However, this trend was replaced with an unpredictable climate with cooler and more humid weather.

These changes may seriously affect the harvest calendar which often starts at the beginning of the year in specific seasons. Also, the change in temperature can also lead to the fluctuation of agricultural production, particularly rice production.

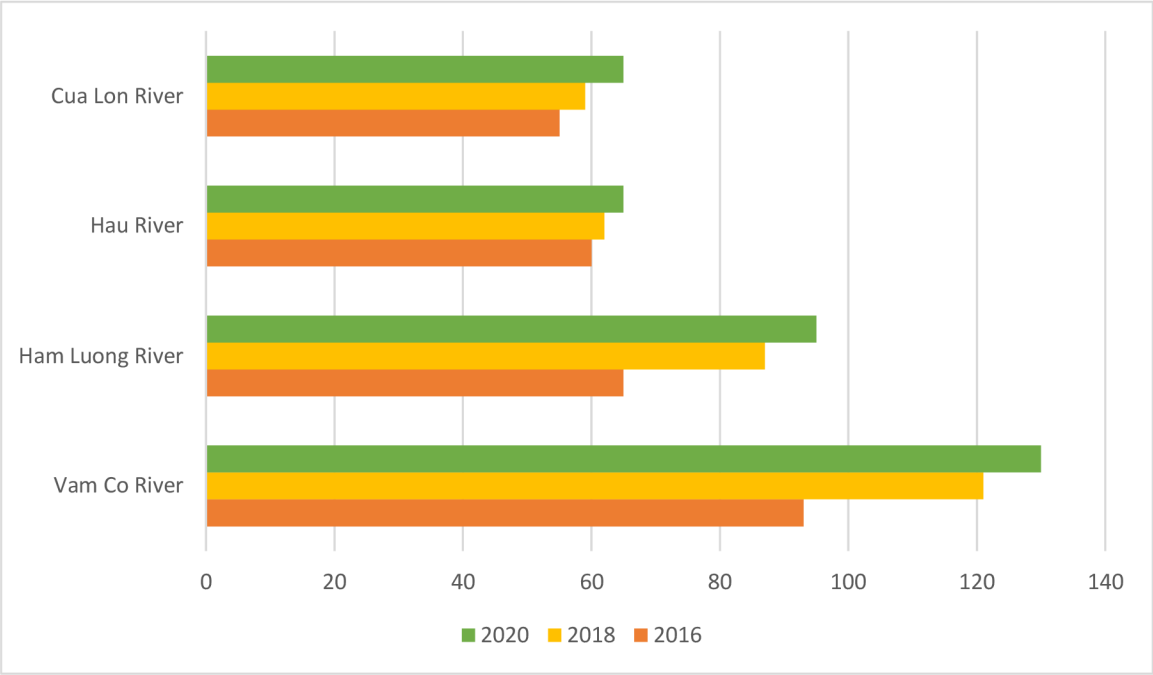

Figure 9 Salinity intrusion rate in Mekong Delta (source: Data Collected)

Besides, there is also a new issue in the neighborhood, which is known as the severe salinity intrusion. Famous for fertile soil and rich freshwater natural supply, the delta has had to face this emerging problem recently since 2020. Because of the condense system of big rivers, canals, and artificial lakes, most agricultural activities in the neighborhood relied heavily on the fresh water supply and the huge area of land. However, since 2020, when the salinity instruction started becoming serious without a specific tendency, the rice productivity and other crops declined significantly.

The tendency of the intrusion reflected in the graph has presented an increasing threat to the agriculture of neighborhoods close to big rivers. The speed of this increase is also recorded with more than 40%, which can quickly cover a large area merely in a few years.

Some other regional features and natural conditions for the agricultural development were also recorded, focused mainly in three locations (including Vinh Long, Long An, and Dong Thap). The time frame in the measurement and comparison table accounted for 5 years (between 2015 and 2021).

While the water speed is much slower in 2021 compared with 2015, the total amount of rainfall water and the water level in rivers increased significantly. This is a possible reason for flash floods when there are seasonal heavy rains. The water level increase is also known as a popular cause that led to flooding events in the rainy seasons. In 5 years, this level has

gone up nearly a meter, which resulted in other natural impacts such as landslides in neighborhoods near large rivers or waterways. The figure also explained the higher flood level in recent years.

Table 9 The measurement and comparison for 5 years between 2015 and 2021 (source: Data Collected)

Water Flow Speed	32% lower than usual (2015-2021)
Total amount of rainfall water	250 mm in rainy seasons (nearly 100mm higher)
The water levels in the rainy seasons	2.5m (0.9m higher)
Salt water intrusion	0.9ml/l (0.4ml/l higher)
Number of seasonal storms	250 (27 more than usual)
Flood level	1.4m (0.4m higher)

Despite a large amount of rainwater during the rainy season, the dry and hot season witness the severe shortage of fresh drinking water, which is a part of the drought. Between 2015 to 2021, the salt water and salinity intrusion has caused a lot of problems to farmers and agricultural activities[69]. Especially, from 2019 to 2021, the effects of salty water in the dry seasons not only decreased the total area of rice fields, but also caused the destruction to all types of crops in the regions[70]. While the water reserve is limited, the natural water supply was affected due to the high temperature and the demand for farming activities.

[69] VO, H. H., MIZUNOYA, T., & NGUYEN, C. D. *Determinants of farmers' adaptation decisions to climate change in the central coastal region of Vietnam.* 2021, p. 334.
[70] NGO, Q. T . *'Farmers' adaptive measures to climate change induced natural shocks through past climate experiences in the Mekong River Delta, Vietnam'*. 2016, p. 1369.

The following table reflects the change in water demand in different neighborhoods throughout the country, where there are specific agricultural activities.

Table 10 Water demand (source: Data Collected)

	Water Demand			
	2015 Winter-Spring	2015 Summer-Autumn	2021 Winter-Spring	2021 Summer Autumn
Dong Thap	60.015m3	67.500m3	61.200m3	69.630m3
Ha Nam	21.830m3	28.700m3	20.984m3	29.003m3
Long An	72.245m3	74.865m3	71.263m3	75.400m3
Nghe An	43.078m3	43.289m3	42.988m3	44.002m3
Quang Binh	34.160m3	35.672m3	33.869m3	36.527m3
Vinh Long	84.060m3	85.214m3	83.753m3	86.014m3

The total demand of water is much higher in southern provinces due to the wet rice production and related agricultural activities. The figures listed on the table also reflect the

need for water changed slightly and tended to become higher in the summer-autumn crops. This is a part of the reason for the increase in the rice productivity change in the seasonal crop. In addition, the contribution of the natural water supply played an important role in the methods to deal with impacts of natural disasters, particularly the effects of climate change effects.

Table 11Rice productivity (source: Data Collected)

	Rice Productivity			
	2015 Winter-Spring (tons)	2015 Summer Autumn (tons)	2021 Winter-Spring (tons)	2021 Summer Autumn (tons)
Dong Thap	3.43 million	3.67 million	3.12 million	3.87 million
Ha Nam	1.17 million	1.78 million	1.02 million	1.86 million
Long An	3.89 million	2.95 million	3.54 million	3.01 million
Nghe An	2.06 million	2.12 million	1.92 million	2.21 million
Quang Binh	1.58 million	1.97 million	1.49 million	2.03 million
Vinh Long	4.12 million	3.87 million	3.84 million	4.16 million
Total	16.25 million	16.36 million	14.93 million	17.14 million

In addition, the number of total land loss can be recorded in most provinces in the project due to the extreme weather in the neighborhood. For example, in Vinh Long, the loss in agricultural land can be noted in the 5 districts and towns in the province.

Table 12 The number of land loss in Vinh Long (source: Data Collected)

Numbers of Land Loss in Vinh Long		
Districts	Total Area (km2)	Land Loss (km2)
Binh Tan	15.289	271
Long Ho	193	5
Mang Thit	158	23
Tam Binh	280	12
Tra On	258	21
Vung Liem	294	4

Obviously, the largest district, Binh Tan, only slightly suffered from the landslide with only 1,73% of the total land lost whereas this figure is much higher in Mang Thit (14,56%). Other locations throughout the province witnessed a small percentage of loss (e.g. Long Ho with 2,59%, Tam Binh with 4,28%, Vung Liem with 1,3%, etc.). Due to the fertility enrichment by canals and large rivers, which can help to refill the damages of the loss in the region, the effects of landslides and other climate change factors did not significantly change the daily lifestyle and local economy development.

However, the situation is not as positive in other areas such as Dong Thap. With more than 12 districts, small cities, and towns, the number of land loss varied due to the geographic locations and natural features.

Table 13The number of land loss in Dong Thap (source: Data Collected)

Numbers of Land Loss in Dong Thap		
Districts	Total Area (km^2)	Land Loss (km^2)
Cao Lanh	107	26.14
Sa Dec	59.11	9.31
Hong Ngu	121.84	24.38
Cao Lanh	491	16.72
Chau Thanh	246	51.06
Hong Ngu	210	19.17
Lai Vung	238	5.6
Lap Vo	246	1.49
Tam Nong	474	5.17
Tan Hong	311	6.03
Thanh Binh	341	14.08

Numbers of Land Loss in Dong Thap		
Districts	Total Area (km^2)	Land Loss (km^2)
Thap Muoi	528	5.15

A large area, including Cao Lanh, Sa Dec, and Chau Thanh, has to seriously suffer from the total land loss, with 3,4%, 15,75%, 20,75%. As the largest district, Hong Ngu merely lost 24,38 ha, accounting for nearly 20% of the total area. The smallest district, Hong Ngu, has a relatively small amount of land loss, with only 9,1%. This is partly caused by the heavy rains and the seasonal flooding events in the province.

Similarly, Long An, with a large area of agricultural land, also lost thousands of hectares in 2021. With more than 14 districts and towns, the figures and data collected fluctuated in different locations.

Table 14 The number of land loss in Long An (source: Data Collected)

Numbers of Land Loss in Long An		
Districts	Total Area (km^2)	Land Loss (km^2)
Tan An	81.94	12.1
Kien Tuong	204.36	24.03
Tan Hung	249.29	16.17
Vinh Hung	384.52	58.1

Numbers of Land Loss in Long An		
Districts	Total Area (km^2)	Land Loss (km^2)
Moc Hoa	297.64	14.09
Tan Thanh	422.85	26.39
Thanh Hoa	468.37	17.48
Duc Hue	428.92	52.63
Duc Hoa	427.63	44.07
Ben Luc	287.86	16.07
Thu Thua	299.1	3.04
Tan Tru	106.5	0.16
Can Duoc	218.20	14.2
Can Giuoc	215.1	57.6
Chau Thanh	155.24	2.3

As it can be observed, Can Giouc is the district with the highest percentage of land loss (nearly 27% of the total area) while Tan Tru is slightly affected with nearly 2%. The largest district is Thanh Hoa, which only recorded 3,73% of total land loss while the smallest area,

Tan An, has a fairly high percentage (14,76%). Because the land loss is calculated after the flooding event, the exact number may be relatively different in previous years.

5. Discussions and Suggestions

Due to the impact of climate change on the land loss and rice production, it is essential to make appropriate plans to increase yields to ensure the process of sustainable development in the neighborhood.

To handle the water supply, monitor the demand for fresh water supply, and strengthen to manage the regional water allocations, specific drought planning as well as emergency planning is necessary for extreme scenarios. Besides, detailed project design to deal with flood risks and high levels of flood should be considered in permanent projects, which can help to control 15-20% of the impacts caused by flood-event rainfall or the water flows in rainy seasons. Furthermore, to satisfy the water demand for farming and related agricultural activities, a modernized and well-equipped system of reserve lakes and water purified machines should be installed and sufficiently improved.

The improvement of the local infrastructure, especially the system of irrigation, should be put at the top of the list highlighting tasks provinces should consider. The impacts of the land loss in the delta areas can be effectively dealt with based on the facilitated dams and reserve lakes. This means inundated areas can be protected during the rainy seasons and the flow of water can be partly managed when there are heavy rains. Moreover, this is also a good source of fresh water supply in the dry seasons. In addition, modern technology and advanced equipment will be a part of the strategies that most local authorities should include in their plans and projects. However, the budget for appropriate expenses is always a big question to deal with the issue.

Facing the decrease of rice productivity, the application of new rice varieties is a potential solution to deal with the salinity intrusion as well as the land loss. Most provinces are actively supporting projects and experiments to find out the most productive and appropriate variety for the local conditions. Although those models are not an important part of the project's coping with climate change impacts, they have proved their effectiveness in improving and increasing rice production and productivity, particularly wet rice cultivation[71].

[71] SHRESTHA, S. Adaptation strategies for rice cultivation under climate change in Central Vietnam. In *Climate Change Impacts and Adaptation in Water Resources and Water Use Sectors.* 2014, p. 112.

Another important part of the projects to reduce the impacts of climate change is to support vulnerable households. Poorer farmers with low incomes or families of ethnic groups who could not have available access to modernized farming methods should be located in the top list for the labor force support in financial support programs by the local government, national and international organizations. Financial arrangements and support (e.g. debt package with low interest, donations, or sponsor investments) can be a helpful idea to increase and encourage the participation from the community and effectively enhance the workforce in the sector[72]. Specifically, the intensification of the rice production process may bring higher yield while the role of home labor can help to protect the land as well as increase productivity.

To boost the rice yield, agricultural intensification is an essential approach. The application of the method can lead to a positive result. The average rice yield will increase at least by 6 percent, particularly the Mekong River Delta and the North Central Coast (with about 10 percent). The yield will probably increase higher if the infrastructure in rural areas of the northern areas can be improved.

Besides, the government policies and guidelines focusing on vulnerable regions can be an effective measurement to augment the rice yield. The Central Highlands can increase the productivity of rice production by 10 percent with relevant laws and regulations to improve the agricultural activities and labor quality.

The connection between climate change impacts and relevant strategies to deal with them should be strengthened. Currently, the Vietnamese government has worked with several stakeholders to develop a wide range of measures as well as to plan multiple activities in order to cope with the influences of climate change at different levels, ranging from local to central levels[73]. Most main hazards counted in the projects may consist of typhoons, floods, and droughts.

[72] ARNDT, C., TARP, F., & THURLOW, J. *'The economic costs of climate change: a multi-sector impact assessment for Vietnam*'. 2015, p. 4133.

[73] YU, B., ZHU, T., BREISINGER, C., & HAI, N. M. *Impacts of climate change on agriculture and policy options for adaptation: The Case of Vietnam* (No. 1015). 2010, p. 4.

6. Conclusions

The impacts of climate change on agriculture in Vietnam can be observed in different aspects. The increasing total areas of land loss and the influences on rice productivity are among the consequences of the changes in the temperature and weather conditions. Besides, the water demand and larger inundated areas in delta regions or coastal neighborhoods are noted in the project. To deal with the climate change effects, recent solutions in provinces should include plans with the systems of irrigation infrastructures, modernized facilities and equipment. Together with relevant policies by the government, as a result, the climate impacts can be alleviated at a certain level.

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Appendix

Table 1. Vietnam maps (source: IMHEN)

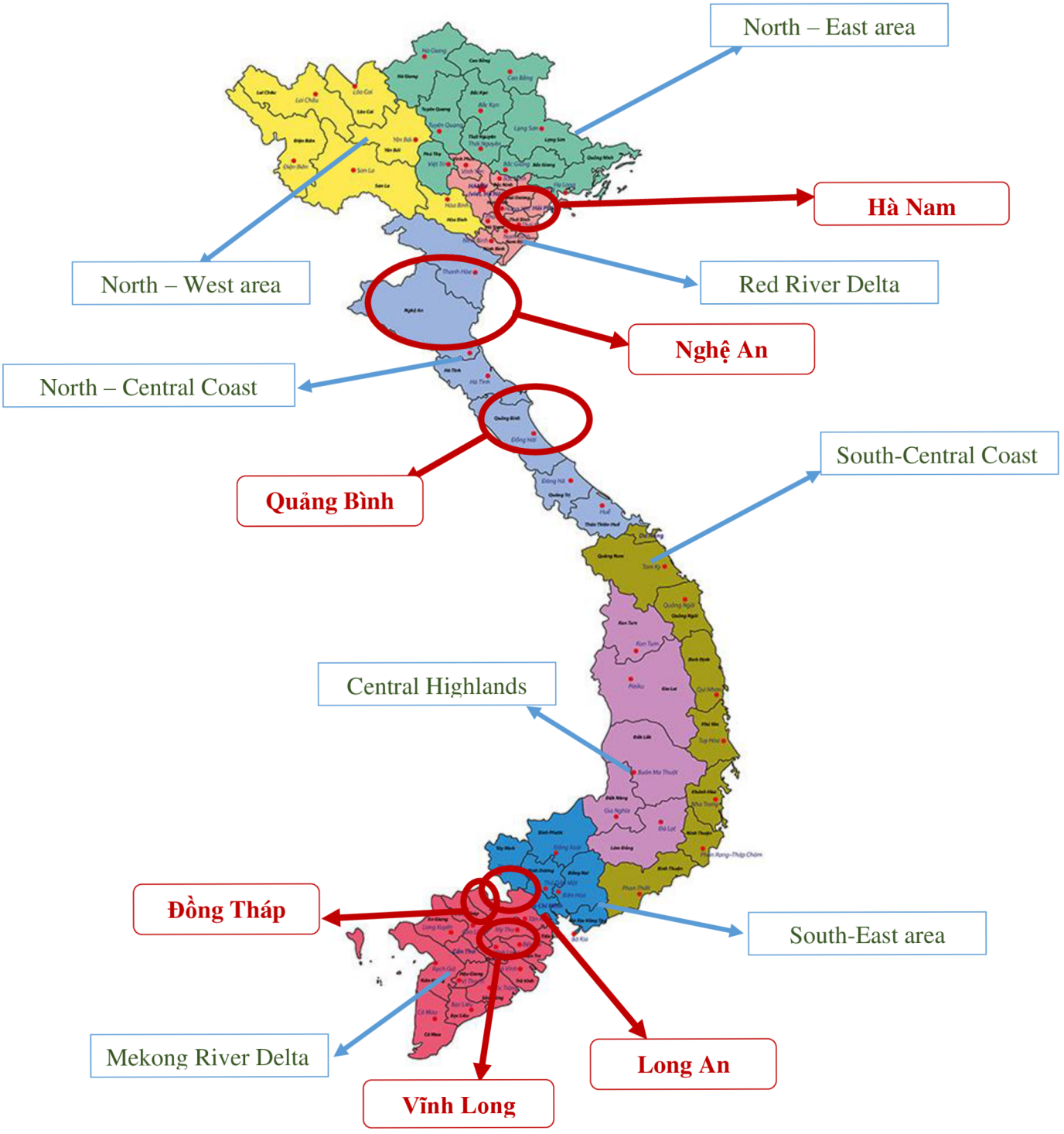

Table 2. Changes in Temperatures in Vietnam (source: Data Collected)

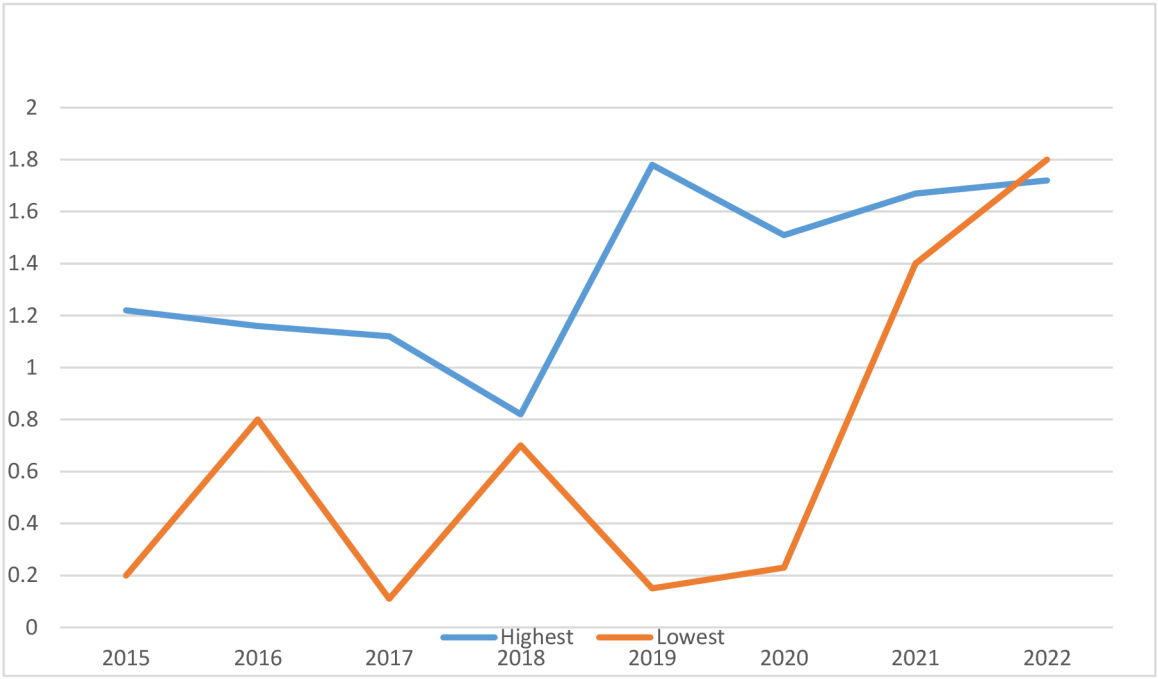

Table 3. Water Demand in Vietnam (source: Data Collected)

	Water Demand			
	2015 Winter-Spring	2015 Summer-Autumn	2021 Winter-Spring	2021 Summer Autumn
Dong Thap	60.015m^3	67.500m^3	61.200m^3	69.630m^3
Ha Nam	21.830m^3	28.700m^3	20.984m^3	29.003m^3
Long An	72.245m^3	74.865m^3	71.263m^3	75.400m^3
Nghe An	43.078m^3	43.289m^3	42.988m^3	44.002m^3
Quang Binh	34.160m^3	35.672m^3	33.869m^3	36.527m^3
Vinh Long	84.060m^3	85.214m^3	83.753m^3	86.014m^3