# CHAPTER I. INTRODUCTION

## A. Background

Food security is a very important issue for developing a growing global population. In addition to enough food to feed the world's population, it is possible to predict what will be produced in the next seasons, even a few years. Agricultural adaptation can largely reduce the potential negative impacts of climate change and climate variability on crop yields (Lin, 2011). In addition to improving arable land and irrigation systems and developing new varieties suitable for each farming area to increase productivity and profit for rice growers, many developed countries have applied technology to crop cultivation. One of the advances in agricultural technology is crop modeling, a formal way to present quantitative knowledge about how a crop grows in interaction with its environment. Using weather data and other data about the crop environment, these models can simulate crop development, growth, yield, water, and nutrient uptake. A crop comes to terms with our overview of the key and ecological phenomena that govern crop growth and development in mathematical equations and logical processes (Yin, Struik, & Goudriaan, 2021).

Using crop models is a formal method for quantitative learning about how a crop grows and interacts with its environment. These models use meteorological information and other information about the agricultural environment to simulate crop development, growth, yield, water, and nutrient absorption. Daily meteorological data such as solar radiation, maximum and minimum temperatures, rainfall, irrigation, soil properties, starting soil conditions, cultivar characteristics, and crop management are all included in the data utilized in crop models (Boote, Jones, & Hoogenboom, 2018). In addition, crop models are mathematical programs that gather quantitative data from agronomy and physiology experiments to characterize and anticipate crop growth and development (Chenu, Porter, Martre, Basso, Chapman, Ewert, Bindi, & Asseng, 2017). In a matter of minutes, they can recreate a variety of seasons, settings, conditions, and situations (Hoogenboom, Porter, Boote, Shelia, Wilkens, Singh, White, Asseng, Lizaso, & Moreno, 2019).

Crop models contribute to agriculture in many ways by exploring the dynamic processes among the atmosphere, the crop, the soil, pest management, breeding, and assessing the impact of climate change (Asseng, Zhu, Basso, Wilson, & Cammarano, 2014).

Climate variability and uncertainty have been key factors influencing cropping systems' performance, adaptation, and planning. Climate variability is a source of uncertainty and risk in agriculture and is likely to increase due to the changes in the magnitude and frequency of extreme weather events (Hartmann, Gill, Opperman, & Harrison, 2013). Thus, agricultural decisions and policymakers are increasingly interested in tools for reducing climate uncertainty and risk.

Crop modelings have been used by many countries in that they can quite accurately estimate crop growth statuses, such as biomass and yield, and predict future climate change's impact because there are many gains for growers when adopting a crop model, such as:

- Improved yield predictions: Crop models use complex algorithms and weather data to simulate how crops will grow under different conditions. The crop model can help farmers predict their yield more accurately, which can be used for crop, marketing, and financial planning.

- Optimized management practices: Crop models can help farmers optimize their management practices by predicting the best time for planting, irrigation, fertilization, and harvesting. This can help farmers reduce input costs and increase yields, resulting in higher profits.

- Risk management: Crop models can help farmers manage risk by predicting the impact of climate change, pests, and diseases on crop yields. This information can be used to develop contingency plans to minimize the impact of negative events on crop yields and profits (Eckstein, Hutfils, & Winges, 2018).

- Improved sustainability: Crop models can help farmers optimize their use of natural resources such as water, fertilizer, and pesticides. The crop model can reduce the environmental impact of farming practices and improve the long-term sustainability of farming operations.

- Research and innovation: Crop models are constantly being improved and updated with new data and scientific findings. This ongoing research and development can lead to new crop varieties and management practices better adapted to local conditions, resulting in higher yields and profits for farmers (Shabani and Sepaskhah, 2019).

Regarding climate change in Vietnam, in an annual assessment of the countries most affected by extreme weather changes between 1997-2016, Vietnam was categorized 6th in the Global Climate Risk Index 2018 (Eckstein, Hutfils, & Winges, 2018). Besides the influence of irregular and extreme rain and sunlight, such as too much rain or sunshine in a short period and lack of irrigating water, the other effect seems to be extreme temperatures following the annual warming trend. Compared with the temperature background from 1986 - 2005, the average yearly temperature in An Giang province (a southwestern province of the Mekong Delta) increased by 0.8 $^oC$ (0.4-1.2 $^oC$) in 2016 - 2035, increased by 1.4 $^oC$ (1.0-2.0 $^oC$) in 2046-2065 with RCP4.5. With the current trend, the increase in temperature would likely go faster. Under the RCP8.5 scenario, the temperature would rise by 0.9 $^oC$ (0.6-1.3 $^oC$) in 2016-2035 and increase by 1.9 $^oC$ (1.4-2.6 $^oC$) 2046 - 2065. The highest temperature could reach 42.5 $^oC$ in 2020, 43 $^oC$ in 2050, and 44 $^oC$ in 2100 (Nguyen, Nguyen, Tran, Nguyen, & Va, 2020). Increased night temperature negatively affects the reproductive stage of rice, reducing the effect of increased atmospheric $CO_2$ concentration, reducing dry matter accumulation, and reducing yield (Cheng, Sakai, Yagi, & Hasegawa, 2009).

Rice and maize have been the two most important food crops of Vietnam and An Giang province from the past to the present. In An Giang province, to develop and manage these two crops sustainably and adapt to climate change, applying high technology to agricultural production and management, the SIMPLECrop crop model was recommended for implementation in the following:

***About theoretical knowledge in agriculture of SIMPLECrop model:***

- A crop model created from scratch, designed to be open-source, and capable of incorporating additional modules.

- While the SIMPLECrop model is simpler than previous models used in Vietnam, with fewer parameters and greater ease of use, it maintains a high level of accuracy due to its customization for the research location. This customization includes specific parameters related to soil characteristics, climate, species parameters, cultivars, and irrigation, making it well-suited for the study's context.

- Constructed entirely using the open-source platform RStudio, the SIMPLECrop model offers the flexibility to incorporate additional modules, such as those for variety, pests and diseases, fertilizer formulas, altitude, and soil slope. Moreover, it allows for proactive coding of commands tailored to specific simulation objectives.

- The model has the capability to forecast biomass and yield under scenarios of rising temperatures and increasing $CO_2$ concentrations in future years.

***Conducting the SIMPLECrop model research will bring the benefits and necessity to growers and local agricultural managers:***

- The current crop models in An Giang were complex and unfamiliar to growers, agribusinesses, and local agricultural managers. Therefore, it is necessary to have a model that is relatively easier to use.

This model does not need to generate too detailed data about species parameters to build. Therefore, it is accomplished faster and with less cost. Moreover, the model will be made on open-source code with the Rstudio platform. As a result, adding more modules to simulate each specific purpose is possible.

- Farmers can choose the right sowing/planting time for each region with different climate conditions and soil types, which produces higher yields. Therefore, the SIMPLECrop crop model can support decision-making in crop planning.

- Agricultural cooperatives, rice production and trading enterprises, and provincial agricultural departments can know in advance how much production they will harvest.

## B. Problem statement

Climate variabilities have emerged as a principal global concern, affecting regions worldwide, with Southern Asia and particularly Vietnam experiencing profound impacts. The Mekong Delta, an agriculturally vital area, stands out as one of the regions most significantly impacted by climate fluctuations. Recent scenarios in Vietnam predict increased temperatures, altered precipitation patterns, and heightened climate extremes, necessitating a detailed examination of these changes.

Climate change-induced adaptations, such as rising temperatures and increased atmospheric $CO_2$, significantly challenge the productivity and biomass formation of rice and maize crops. These climate variabilities cause substantial threats to agriculture, particularly to the cultivation of rice and maize. The impact of these variations extends beyond the immediate environment, influencing global food security and socioeconomic well-being.

Crop modeling emerges as a valuable tool to comprehend and mitigate these challenges. Among various crop modeling techniques, the SIMPLECrop model stands out for its flexibility and effectiveness in simulating biomass, yield, and crop responses under diverse climate scenarios. Its comparative advantages lie in its adaptability to regional conditions and its ability to provide quite accurate predictions, making it a choice asset for researchers and policymakers.

The consequences include shifts in temperature, altered rainfall patterns, and an increase in extreme weather events, all of which directly impact crop yields and agricultural sustainability. The Cho Moi District, being a largely agricultural region, is particularly susceptible to these changes, threatening the livelihoods of local farmers and the region's food security. The choice of Cho Moi District in An Giang Province as the focal point of this research is informed by the district's vulnerability to climate change and its economic dependence on rice and maize cultivation. The unique climatic conditions, soil characteristics, and agricultural practices in this region necessitate a tailored approach to modeling for precise predictions and informed decision-making.

The primary motivations behind this research stem from the pressing need to address climate-induced threats to agricultural sustainability in An Giang Province. Through the simulation of biomass, yield, and responses to climate variabilities, this study aims to find essential insights into the intricate dynamics of rice and maize cultivation. It truly serves as a tool to assist crop-growing companies and rice exporters in planning production and consumption. Additionally, it helps the provincial agricultural department in providing relevant recommendations, delivering benefits, and mitigating risks. In essence, this research addresses a significant knowledge gap by comprehensively modeling and understanding the involved dynamics of rice and maize cultivation in Cho Moi District under the influence of climate variabilities, utilizing the capabilities of the SIMPLECrop model. The outcomes of this study aim to contribute knowledge to inform policies and practices, ensuring food security and economic stability in the region.

**C. Research objectives**

1. Exploring the evolution of historical data over 10 years and the observation data (fields and greenhouses) to developt SIMPLECrop model.

2. Building and simulating SIMPLECrop model for rice and maize about biomass and yield in An Giang province, with a good validation (NSE > 0.65).

3. Forecasting future biomass and yields for rice and maize by simulating them in higher temperatures and carbon dioxide concentration conditions.

**D. Research hypothesis**

1 The exploration of secondary data from 2010 to 2019, coupled with primary data collected through field and greenhouse experiments in An Giang Province, will reveal significant trends and patterns in weather changes, crop yield, and related parameters, providing a robust foundation for the development of crop modeling.

2 The construction and simulation of the SIMPLECrop model for rice and maize cultivation in An Giang Province will result in accurate predictions of biomass and yield, with a validation metric (NSE > 0.65) indicating the model's reliability and effectiveness in representing crop growth dynamics under local environmental conditions.

3 By employing the SIMPLECrop model to forecast future biomass and yields for rice and maize in An Giang Province under simulated higher temperatures and elevated carbon dioxide concentrations, it is hypothesized that the model will provide valuable insights into the potential impacts of climate change on crop productivity.

**E. Research novelty**

The research domain of this dissertation lies within the field of crop modeling, a field utilized in developed nations across vast agricultural landscapes through closed-software. The research gap identified encompasses the absence of crop models tailored to local-scale climatic conditions, soil characteristics, and specific farming practices within small-scale agricultural settings. Such tailored models hold the promise of increased accuracy in predicting crop behavior and performance. Furthermore, there is a pressing need for these models to be user-friendly, enabling easy data collection from field observations and simplified experimental setups with fewer parameters. Currently, there is a shortage of such accessible models with open-source code and user-friendly interfaces.

The novelty of this research lies in its dual capability to address the identified gap while also delivering benefits to agricultural cooperatives, companies in terms of production planning and business strategies, as well as aiding agricultural management decision-making at the provincial level.. This innovative approach not only provides practical solutions to existing challenges but also has the potential to inform policy frameworks, thereby contributing to the overall advancement of agricultural sustainability and productivity.

In this study, novelty was reflected in the following characteristics:

1. The SIMPLECrop model introduces a new and more concise approach by utilizing fewer parameters compared to previous crop models. The study introduces a pioneering approach, tailored to the unique conditions of An Giang Province, Vietnam. This model streamlines the crop simulation process by employing a reduced number of parameters, simplifying the interface for users, including researchers, agricultural companies, and practitioners.
2. Creating an intuitive and user-friendly crop consultation interface accessible via web browsers is another innovation. This user interface integrates soil maps, land-use maps, and sowing/planting schedules to facilitate yield simulation, streamlining the decision-making process for agricultural practitioners.
3. The crop model has been developed on a self-configured open-source system and can be expanded with “optional modules”, providing flexibility for future enhancements and adaptations to suit specific research or application needs.