Predictive Modeling of MPS Production
in Thanh Hoa, Vietnam

1. Contribution

Soil
- Retrieve soil data using R script - Dieu-Anh Le, Fu-Hsin Liao
- Process soil data to accommodate different crops - Fu-Hsin Liao
- Apsim files preprocessing - Fuhsin Liao

Crops simulation under various conditions
- Peanut - Fu-Hsin Liao
- Maize - Jinho Lee
- Sugarcane - Dieu-Anh Le

Weather
- Climate data prediction and preprocessing: Yin-Kai Huang

GAZE data
- Preprocess GAZE data - Yin-Kai Huang
- Visualize Tif file - Yin-Kai Huang

Background researches
- Cost and Profit of each crop - Yin-Kai Huang
- Revenue and Price of each crop - Dieu-Anh Le
- Agriculture practice - Jinho Lee
- Recommendation of the distribution - Yin-Kai Huang

Report writing and Presentation - Dieu-Anh Le, Fu-Hsin Liao, Jinho Lee, Yin-Kai Huang

2. Introduction and Motivation

2.1 Why do we choose Thanh Hoa, Vietnam?

All of our team members are from Asia. Therefore, we decided to choose an Asian country for our simulation. Regarding food, the most commonly cultivated and consumed crop in Asia is rice. However, APSIM does not provide a rice model, so we chose other crops that can be used as food sources for food security. In choosing the regions, we select candidates based on the below criteria.

a. Cultivate other non-rice crops for food.
b. Growing crops with high value-added in other than food.
c. Crops that satisfy conditions a ~ b above are available in the APSIM model.

One region that satisfied all of these criteria was the Thanh Hoa region in northern Vietnam. This ecology is located mainly in the Red River Delta, the second-largest crop-producing area of Vietnam. In general, the climatic and soil conditions in Thanh Hoa province are favorable for the development of diverse agriculture. So we chose Than Hoa, accurately 19° N 105° E, as the region to perform the simulation.

2.2 Why do we choose Maize, Peanut, and Sugarcane?

We selected the top 10 crops with the largest cultivated area as well as models available in APSIM. The crops that satisfy these conditions was Maize, Peanut, and Sugarcane.

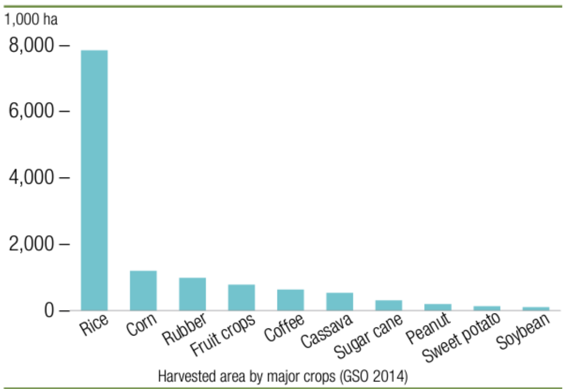


Figure 1. Top 10 crops by harvested area in Vietnam

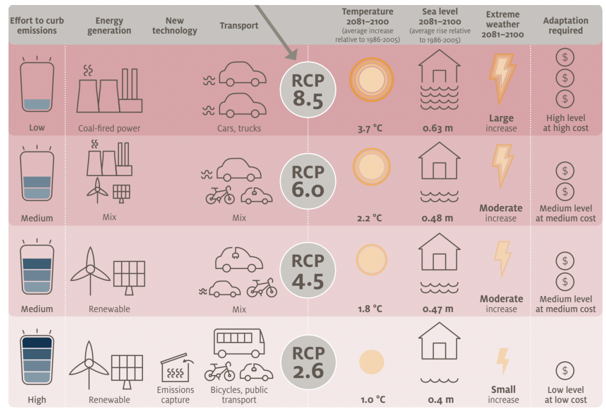


Figure 2. Comparison across different RCP environments

2.2 Why RCP 4.5 and RCP 8.5?

The current emission trajectory in Vietnam exhibits a notable alignment with the RCP 8.5 pathway, as depicted in Figure YY. The selection of RCP 8.5 as the basis for our study was motivated by the desire to obtain yield predictions that closely reflect the prevailing environmental conditions. Conversely, RCP 4.5 was chosen as a comparative benchmark to RCP 8.5, rather than RCP 2.6, due to the overly optimistic nature of RCP 2.6 in terms of its feasibility in the future. Our aim is to simulate a more optimistic yet realistic scenario, envisioning a future characterized by brighter prospects and attainable outcomes.

2.4 Weather in Thanh Hoa

In the northeast Vietnam region, winters are cold and dry, and the summer months of June to August are prone to heavy rain and potential storm damage, particularly in coastal provinces. In the Red River Delta, the annual average temperature is 23.4ºC, with January being the coldest month at 16ºC, and June and July being the warmest months at 28.8ºC. The annual rainfall in this region is approximately 1800mm, with the majority occurring between May and October[1].

2.5 Soil in Thanh Hoa

In Thanh Hoa, alluvium soil (eutric fluvisols) is the most common soil type in the Red River Delta of the northern lowland agro ecological zone[1].

3. Mastery of Tools and Algorithms

Languages and Tools: APSIM, R, Python, Excel

3.1 Weather Data

To procure weather data spanning the timeframe of 2011-2022, we utilize Bestia Pop, a Python package that facilitates access to daily data sourced from NASA POWER. When it comes to future climate data, the Community Climate System Model (CCSM) model presents a reliable prediction of climate conditions for both RCP 4.5 and RCP 8.5. However, it is important to acknowledge that the CCSM model solely provides monthly mean data, which poses a limitation. To address this, our approach involves extending the available weather data for each month to encompass every day within that respective month for the remaining years. The variables we consider in our analysis encompass precipitation, maximum temperature, minimum temperature, and radiation.

3.2 Soil Data

Our soil data of Thanh Hoa, Vietnam is retrieved from ISRIC using R, the library *apsimx*, and the library *ggplot2*. We first use "get_isric_soil_profile" to gather data from ISRIC, and then we process the soil profile to accommodate maize, peanut, and sugarcane. Finally, we used "edit_apsimx_replace_soil_profile" to transform three soil profiles into three APSIM files respectively. In APSIM, we manage to use different tools in the toolbox to get various results including "Automatic irrigation based on water deficit", "FertiliseOnFixedDate", and so on. Besides, we have merged the "experiment" function in APSIM with our simulations to efficiently create a series of experiments. We even use the graph filter command such as "[Clock.Today]>='2011-01-01' and [Clock.Today]<='2040-12-31'" to optimize our graph result.

3.3 GAEZ Data

We downloaded the GAEZ data by selecting the options below.

- Unit: kg DW/ha
- Input-Level: High
- Climate Data Source: GFDL-ESM2M
- Longitude of graphs: 102-110
- Latitude of graphs: 16-24
- Left to right is 2011-2040, 2041-2070, 2071-2100

4. Findings

4.1 Peanut

Peanut is among the top three crops cultivated in Thanh Hoa, Vietnam. Peanut in Thanh Hoa is grown in medium-level farming practices. Medium farming practices of peanuts typically involve several key elements, including irrigation, fertilization, seed selection, and pest control. Based on this information, we design three experiments on three control variables to find the optimized productivity in medium input farming practice.

Experiment 1. Irrigation

The first experimental factor we choose is whether the farming practice includes irrigation or not. We use the "Automatic irrigation based on water deficit" model in Apsim management toolbox to simulate the irrigation farming practice. We set the water threshold to 0.9 and the soil depth to 2000 mm (based on the soil profile). We ran the simulation from 2011 to 2100 and compare the total yield between irrigation and non-irrigation. In Figure 1., the total yield of irrigation farming is **1.16** times higher than non-irrigation farming in 90 years. Thus, we figure the irrigation farming practice might be a better choice in the next 90 years than the non-irrigation one.

Experiment 2. Peanut Population

The other critical factor we picked for the experiment is the sowing population of peanuts. A higher plant population increases the yield but shortens the land sustainability; A lower plant population decreases the current yield but increases the life of the land. To find out the optimized plant population, we use the "Sowing Rule" model in Apsim management toolbox to simulate the yield in 90 years and set the plant population(/m2) from 10 to 2010, step 4000. In Figure 2., the total yield experiences a hike when the plant population switch from 10 to 4010 and increases in a nonsignificant way from 4010(/m2) to 20010(/m2). Based on the experiment result, we decide 4000(/m2) to be the best plant population in the next 90 years.

Experiment 3. Fertilizer Amount

Last but not least, we choose the fertilizer amount to be our last control variable. According to our research, the most common fertilizer type used in Thanh Hoa on peanuts is NO3. To find out the optimized fertilizer amount, we use "FertiliseOnFixedDate" model in Apsim and run an experiment that tests fertilizer amount from 0 kg/ha to 500 kg/ha, step 100 kg/ha. In Figure 3., the total yield experiences a sharp increase when the fertilizer amount switch from 0 to 100 and fluctuates in the rest variables. Considering both the cost and the effect, we decide that 100 kg/ha of NO3 fertilizer is the ideal amount for the next 90 years.

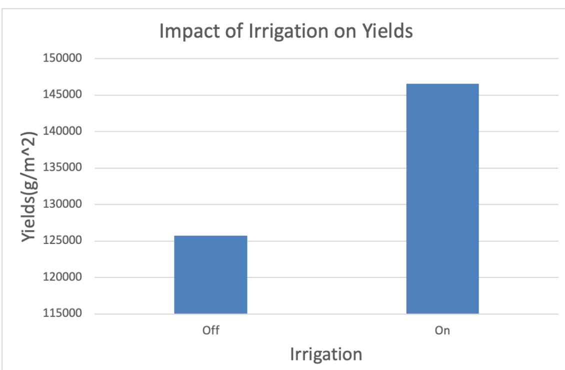


Figure 3. Impact of irrigation on peanut yield

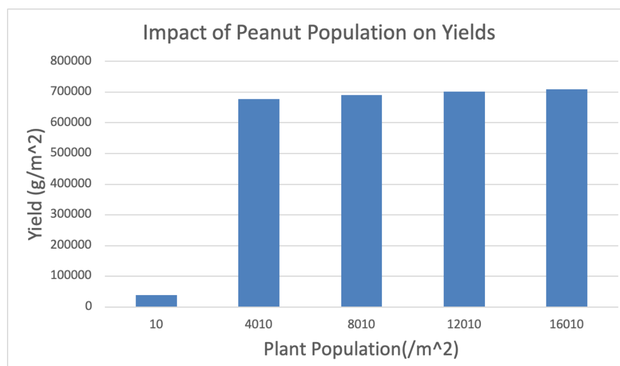


Figure 4. Impact of plant population on Peanut Yield

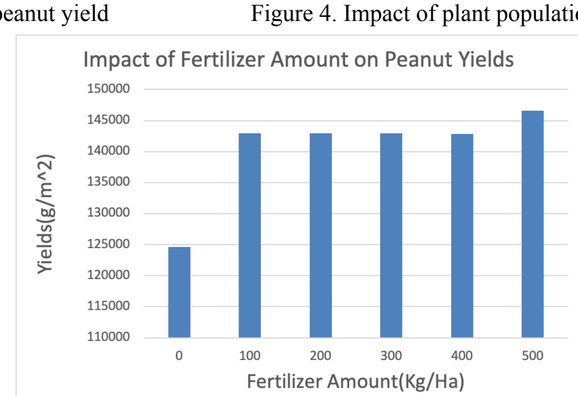


Figure 5. Impact of fertilizer amount on Peanut Yield

Comparison of Peanut Yield with our Finding and GAZE Data

After finding the optimal combination in medium farming practices, we then run the yield simulation on Apsim in the weather of RCP 4.5 with RCP 8.5 (Figure 4.). In our simulation, the yield in RCP 4.5

experiences similar ups and downs to the one in RCP 8.5 but goes slightly higher in each up and down. The total yield in RCP 4.5 is slightly better than the total yield in RCP 8.5, which matches the result in GAZE data. In our simulation, the total yields in three periods 2011-2040, 2041-2070, and 2071-2100 show no significant difference in both RCPs. However, in GAZE data, peanut yield shows a trend of decreasing in RCP 4.5 and fluctuating in RCP 8.5., which does not quite match our finding.

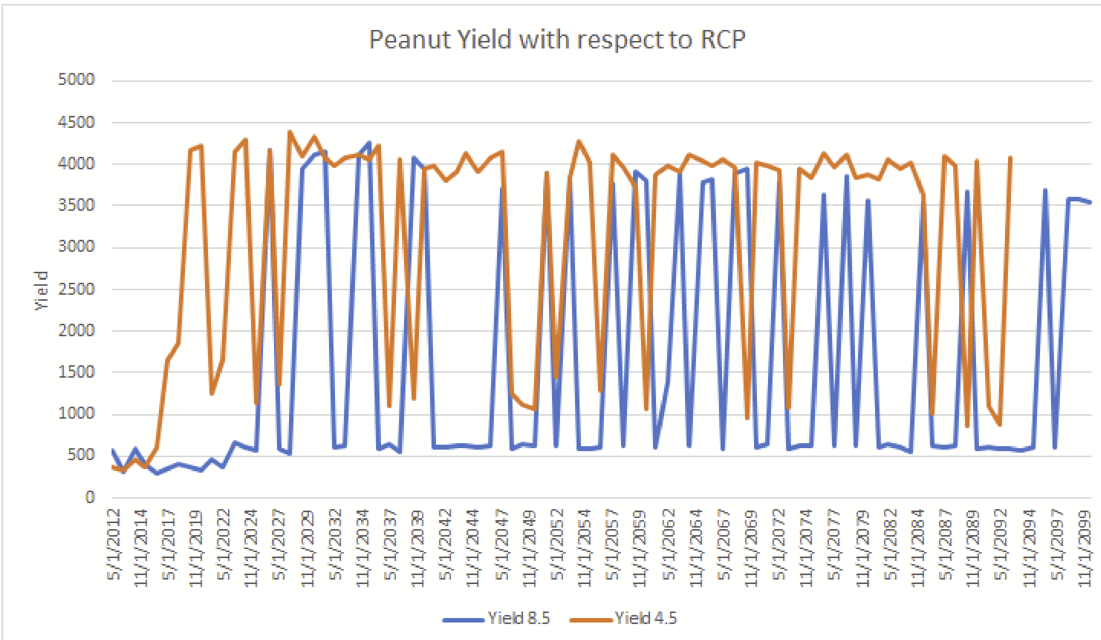


Figure 6. Peanut Yield with Respect to RCP 4.5 and RCP 8.5

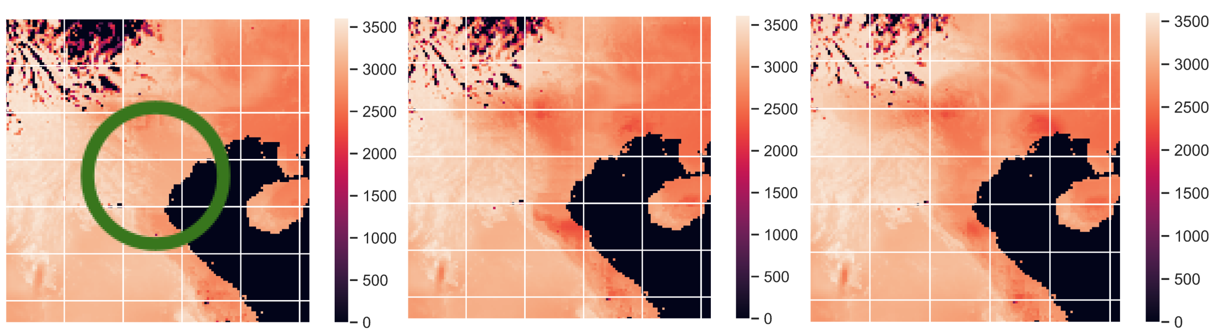


Figure 7. Peanut Yield (Kg/Ha) in RCP 4.5, 2011-2040(left), 2041-2070(middle) 2071-2100(right) from GAZE data

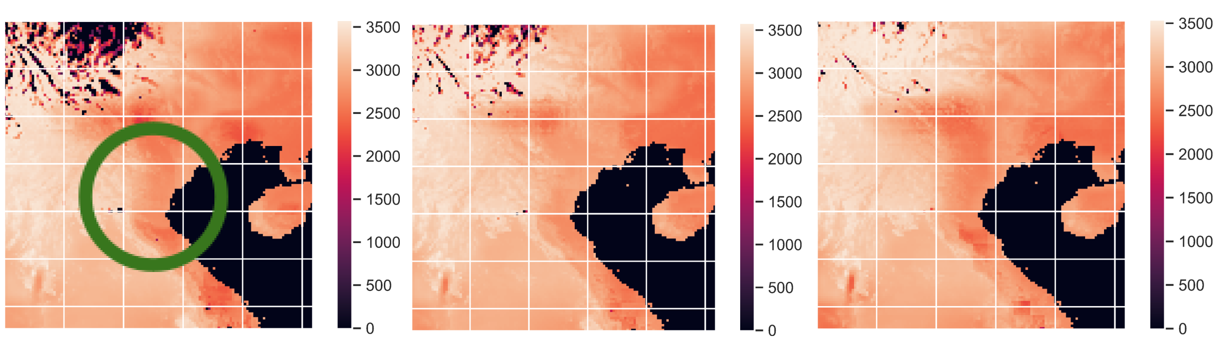


Figure 8. Peanut Yield (Kg/Ha) in RCP 8.5, 2011-2040(left), 2041-2070(middle) 2071-2100(right) from GAZE data

4.2 Maize

Maize is the second most important crop after rice in Vietnam. Maize is an important crop, there's a relatively good source of data for crops cultivated in northern Vietnam. We referenced the "Maize in Vietnam" report by *Dang Thanh Ha* and other authors, which collected data on maize cultivation in Vietnam[1]. Maize is planted either in the winter-spring or spring-summer crop seasons. Regarding the Winter-spring season, maize seeds were planted in September/October and harvested in January. And with regard to the Spring-summer season, maize seeds are planted in January-February and harvested in May. But, Maize is usually planted in the winter-spring or spring-summer crop seasons.

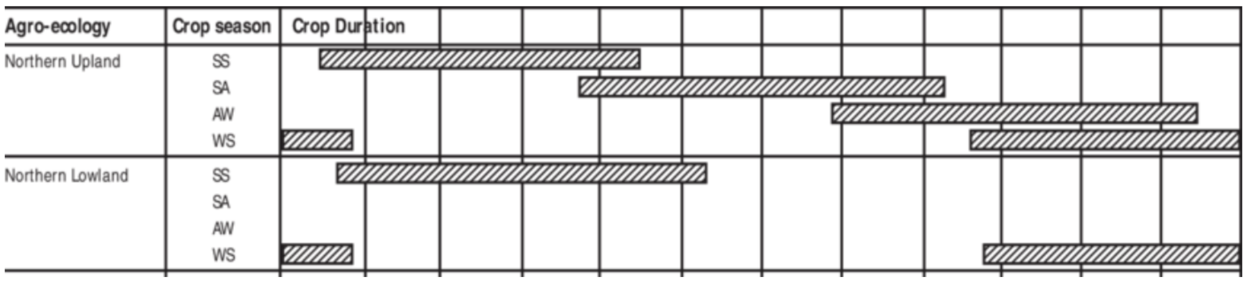


Figure 9. Maize crop calendar, vietnam

Regarding the "Maize in Vietnam" report, popular maize cultivars planted in Vietnam are LVN 10, DK 888, DK 999, LVN 20. Another report indicates that NK 4300, HN 88 are popular maize cultivars in northern vietnam[2]. However, APSIM does not provide cultivar lists related to that cultivar in the maize model. This resulted in the limitations of accurate simulation.

Fertilizers

The report categorized Vietnam into six regions and provided data on the fertilizer used in each region. In the simulation, we tried to use the information of fertilizers actually used in different regions of Vietnam. Because the data is similar in some regions, We choose 4 regions in this report. These data are summarized in Table 1.

Regions	Urea (kg/ha)	Manure (kg/ha)	NPK (kg/ha)
F1 (Northern lowland)	270	8,100	0
F2 (Northern upload)	216	4,750	177
F3 (Central Highland-Central Coast Upland)	66	0	86
F4 (Southeast-Mekong-Delta Upload)	250	0	150

Table 1. Average fertilization used in maize cultivation in each region

Planting densities for simulation

Regarding plant densities, we have categorized them into three main categories. Table 2 shows detailed data regarding each category. The data related to each density was then input into the 'Sow using a variable rule' script of the maize model to simulate.

Plating densities	Rowing space(mm)	Plant population(/m^2)
D1 (Narrow row spacing)	550	10
D2 (Conventional row spacing)	825	5.3
D3 (Wide row spacing)	1,050	2.78

Table 2. Detailed information for each of the densities

Maize modeling for APSIM

The variables and values in Table 3 were used as constant values in the script for maize modeling without any changes for simulation. This value is based on information from Pokhariyal et al[3].

Variable	Value
Minimum extractable soil water for sowing (mm)	30
Accumulated rainfall required for sowing (mm)	50
Duration of rainfall accumulation (d)	5
Sowing depth (mm)	30

Table 3. Average fertilization used in maize cultivation in each region

In our area, we will investigate the yield volume simulation results based on weather and soil data, each of RCP 45 and RCP 85. However, before doing that, in our target area, we want to figure out the optimal parameters for maximizing the yield volume of maize. And after calculating the parameters, we will simulate using those optimal parameters. Research conducted in northern Vietnam, which is our target area, suggests that planting densities and fertilizer rates have the biggest impact on yield. Thus, the plaiting densities and fertilizer rates to produce the maximum yield for each RCP were simulated[4].

Experiment 1. RCP 4.5 scenario

The combination of the values specified in D1 through D3 and the values specified in F1 through F4 creates 12 different simulation conditions. Each condition was named DnFn and simulated using APSIM. The results of the 12 experiments are shown in the following graph of maize yield over time.

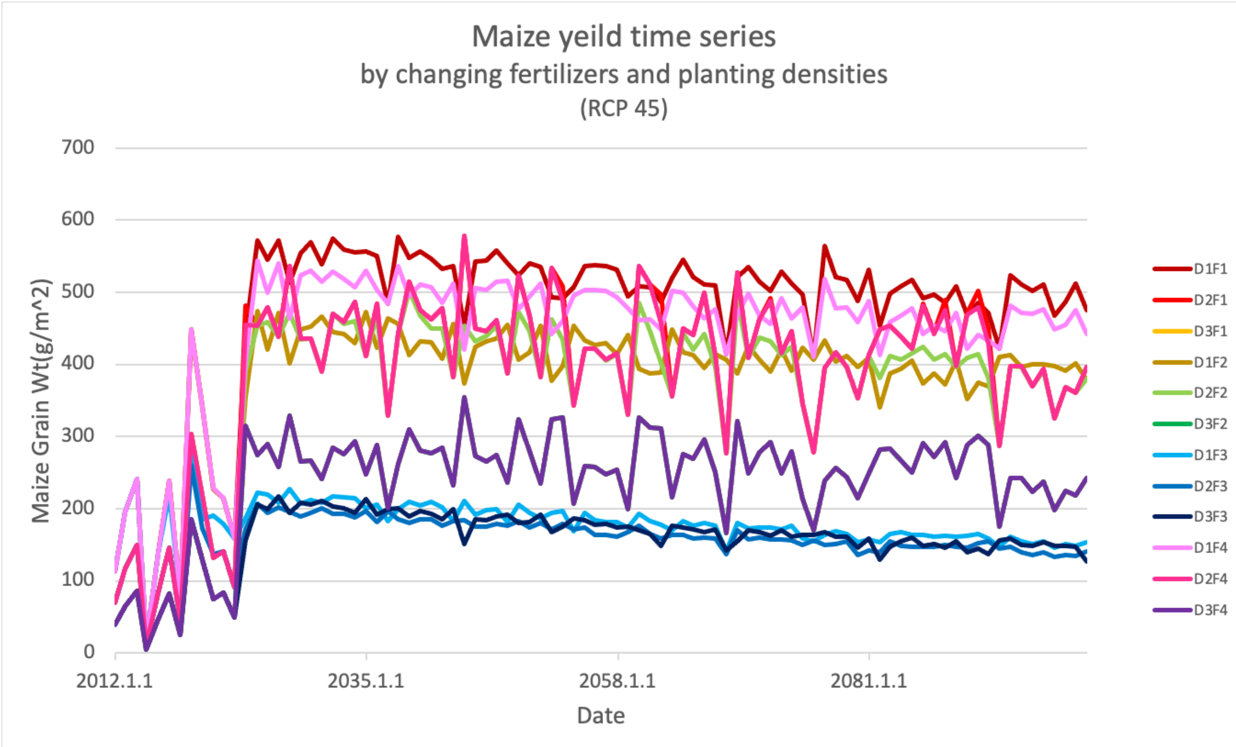


Figure 10. Simulation results of maize yields under variation of planting densities and fertilization in RCP 4.5 scenario

From the above simulation results, the average annual maize yield for each condition is shown in Table 4. From these results, we can conclude that the highest yields can be expected when using fertilizer combinations commonly used in the north lowland of Vietnam and when planting maize in narrow spacing. We simulated maize production under the RCP 4.5 scenario based on this D1F1 condition.

	D1	D2	D3
F1	473.6	391.8	237.9
F2	385.3	373.2	237.9
F3	178.6	159.2	158.5
F4	442.4	390.1	237.9

Table 4. Simulation results of average maize production(g/m^2) per year under the RCP 4.5 scenario

Experiment 2. RCP 8.5 scenario

We simulated the scenarios for RCP 8.5 in the same way as we did for RCP 4.5 above. The results are shown below.

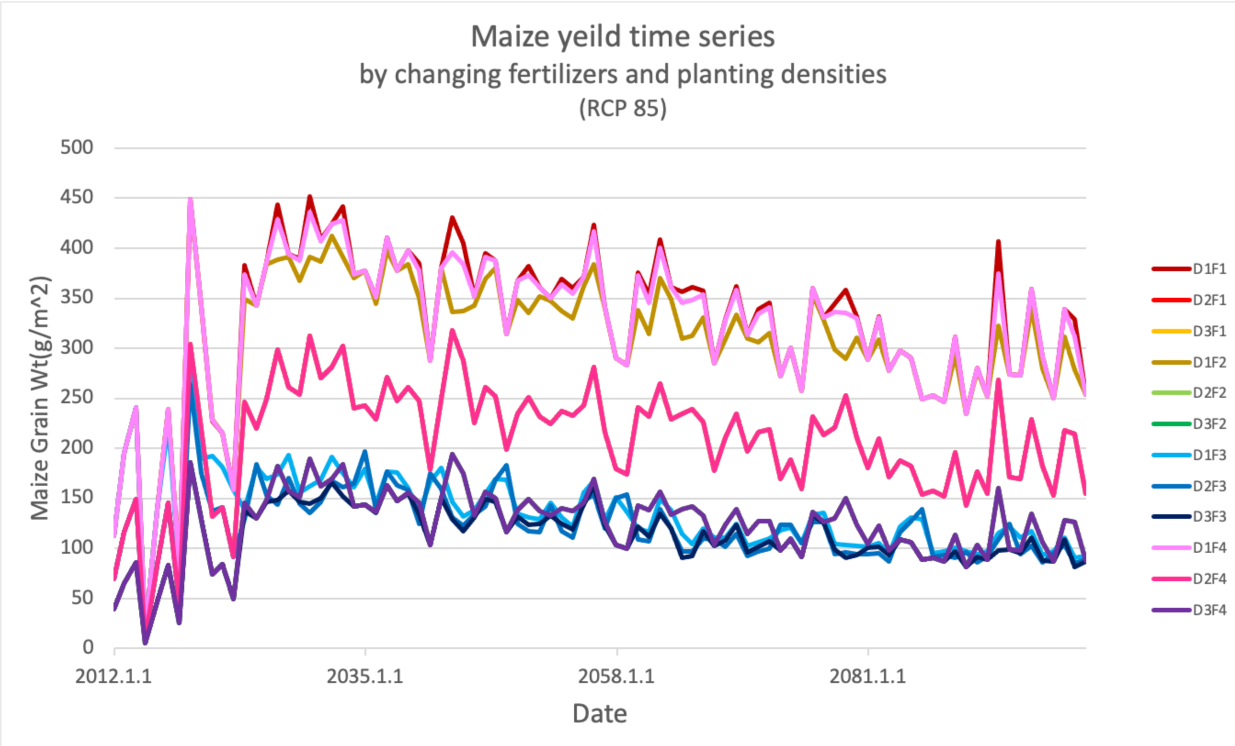


Figure 11. Simulation results of maize yields under variation of planting densities and fertilization in RCP 85 scenario

Same as in the RCP 4.5 scenario, we can conclude that the highest yields can be expected when using fertilizer combinations commonly used in the north lowland of Vietnam and when planting maize in narrow spacing.

	D1	D2	D3
F1	324.4	209.0	123.3
F2	308.0	209.0	123.3
F3	136.8	123.8	111.8
F4	321.2	209.0	123.3

Table 5. Simulation results of average maize production(g/m^2) per year under the RCP 85 scenario

Regardless of the RCP 4.5 and RCP 8.5 scenarios, the highest annual maize yields are expected when simulated under conditions of D1F1 at all times.

Simulation results for RCP 4.5 and RCP 8.5 scenarios
Simulations were performed using the RCP 4.5 scenario and the RCP 8.5 scenario APSIM using the value of D1F1. The graphical representation of each result as a function of production over time is shown in Figure 12. For the maize crop, the simulation results show that the RCP 4.5 scenario has higher yields in our target area.

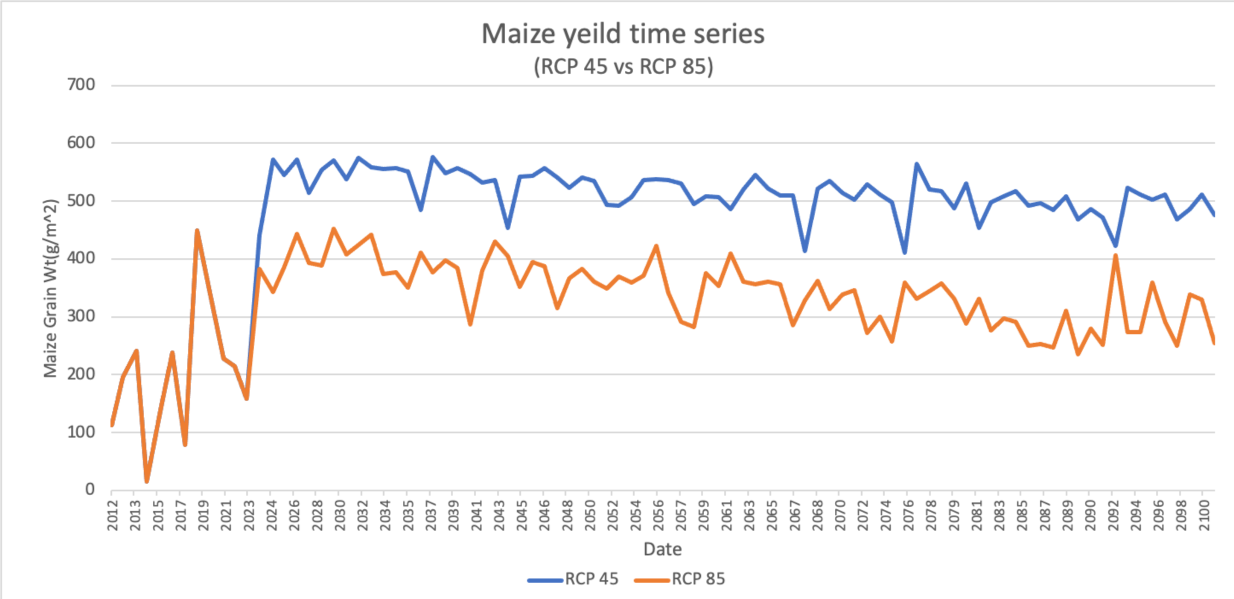


Figure 12. Compare yields over time by RCP 4.5 and RCP 8.5 scenarios

Comparison of Maize Yield and GAEZ Data

Since APSIM only supports rain-fed conditions for the maize model, only rain-fed conditions were considered. Figure XX above shows that maize yields under the RCP 4.5 scenario are higher than under RCP 8.5. This result also aligns with the data from GAEZ, which indicates that RCP 4.5 yields are higher than RCP 8.5. In the graph in Figure XX, the average maize yield decreases over time in the RCP 4.5 scenario. This is consistent with the deceleration of production over time in the GAEZ data, Figure XX.

Year	Yield (Kg/ha)	
	RCP 8.5	RCP 4.5
2023 - 2040	3,900	5,450
2041 - 2070	3,590	5,180
2071 - 2100	3,000	4,960

Table 6. Estimated maize production for each period

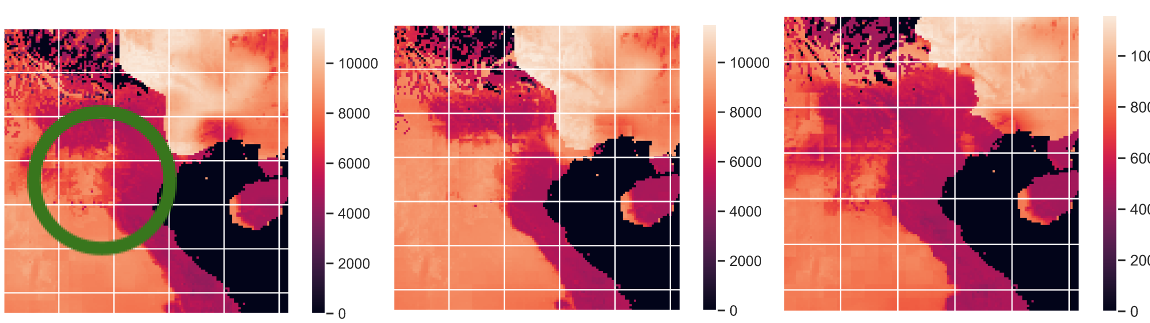


Figure 13. Maize Yield (Kg/Ha) in RCP 8.5, 2011-2040(left), 2041-2070(middle) 2071-2100(right) from GAZE data

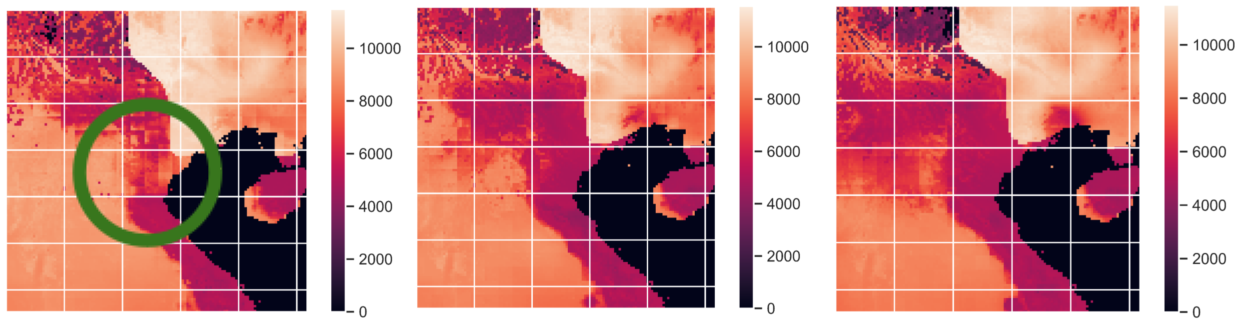


Figure 14. Maize Yield (Kg/Ha) in RCP 4.5, 2011-2040(left), 2041-2070(middle) 2071-2100(right) from GAZE data

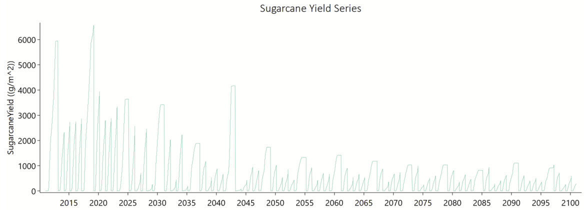
4.3 Sugarcane

The cultivation of sugarcane involves various factors such as variety selection, land preparation, planting time, irrigation, fertilization, weed control, and pest management. In order to optimize the yield and productivity of sugarcane crops, it is important to explore different aspects of farming practices.In this research, we focus on three key aspects: the type of fertilizer, its application schedule, and the optimal sowing time. By adjusting these factors, we aim to identify the combination that maximizes the yield and overall performance of sugarcane crops.

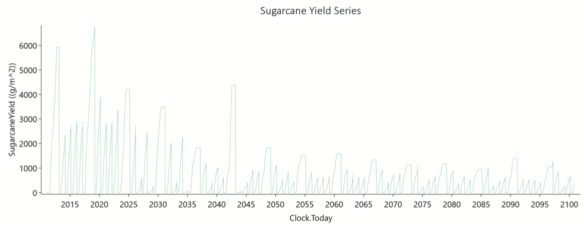
While it is important to evaluate the impact of individual factors on crop yield, it's worth noting that agricultural systems are complex and often exhibit interdependencies among different factors. Considering factors in isolation may not provide an accurate representation of the optimal model for sugarcane cultivation. In reality, the effectiveness of different factors can vary depending on their interactions and synergies. For example, the effect of fertilizer concentration may be influenced by planting depth, and vice versa. Ignoring these potential interactions can lead to suboptimal results. To obtain a more comprehensive understanding of the optimal model for sugarcane cultivation, it is advisable to conduct integrated analyses that account for the interdependencies among different attributes.

Experiment 1. Fertilizer Type

The crucial chemical elements required for sugarcane growth are Nitrogen, Phosphorus, Potassium, and other micronutrients. We tested the simulation on different types of fertilizer with different quantities and observed that there were insignificant differences between the types as shown in the figures below. For instance, varying the amount of UreaN from 60 kg/ha to 180 kg/ha (which is the suggested amount), we observed negligible differences in yield. We then proceed to change the type of fertilizer to DAP and vary its amount within the suggested range of 40-80 kg/ha, where we see a reduction in output. Hence, conclude that when it comes to fertilizer, quality plays a more important role than quantity.



60kg/ha



180kg/ha

Figure 15. Sugarcane yield with different fertilizer amount

Sugarcane growth relies on essential chemical elements, including Nitrogen, Phosphorus, Potassium, and various micronutrients. We conducted simulations using different types of fertilizers and varying quantities to assess their impact on crop performance. Surprisingly, we observed minimal differences among the fertilizer types tested. For instance, we examined the effects of varying UreaN quantities from 60 kg/ha to the suggested amount of 180 kg/ha. Interestingly, the variations in yield were insignificant, indicating that the quantity of UreaN within this range had little influence on the output. However, there were notable differences when we shifted our focus to another fertilizer, DAP, and adjusted its quantity within the suggested range of 40-80 kg/ha. In this case, we noticed a reduction in crop yield as the quantity of fertilizer increased. This highlights the importance of selecting high-quality fertilizers that provide the necessary nutrients in an optimal form and balance for sugarcane growth.

With NPK being the major element responsible for the growth of sugarcane, other types of fertilizers in APSIM either did not have all the required components or had an incorrect ratio of elements. This outlines one limitation of our study is that with Nitrogen, Phosphorus, and Potassium (NPK) being the major elements essential for sugarcane growth. However, after evaluating various fertilizers available in the APSIM model, most alternative fertilizers did not contain all the required components in the correct ratios compared to NPK fertilizer. As a result, we proceed with DAP (Di-ammonium Phosphate), as supported by existing research. Although DAP may not provide the same yield benefits as UreaN, its availability and established usage make it a practical choice for sugarcane farmers in the region. Therefore by choosing DAP as the fertilizer of interest in our simulations, we aim to provide insights and recommendations that align with the prevailing farming practices in Vietnam. This approach ensures the practicality and applicability of our research findings for sugarcane cultivation in the local context.

Experiment 2. Changes Sowing time based on the raining season

Next, we changed the planting schedule and set the sowing season to the beginning of the rainy season and found that the rainy season begins around February for RCP 8.5 and April for RCP 4.5. We ran the simulations for several months around the rainy season and collected the following yield result.

Many papers suggested starting sugarcane plantation during the onset of the rainy season, which occurs around May for RCP 8.5 and April for RCP 4.5. However, the result from the simulation shows that the optimal planting season for sugarcane are October and December for RCP 8.5 and 4.5 respectively based on the total yield across 90 years. If we started planting sugarcane based on the suggested time period, then the total yield for both RCP appears to be approximately the same.

Initially, common recommendations suggested starting the plantation during the onset of the rainy season, typically occurring around May for RCP 8.5 and April for RCP 4.5. However, the resulting yield data from our simulations revealed that the optimal planting seasons for sugarcane are October for RCP 8.5 and December for RCP 4.5. These findings are based on evaluating the total yield across a span of 90 years. These results indicate that deviating from the conventional planting time and adjusting it to October for RCP 8.5 and December for RCP 4.5 can potentially optimize the overall yield of sugarcane cultivation. This insight challenges the prevailing recommendations and highlights the importance of considering local climatic conditions and the specific requirements of sugarcane crops for achieving optimal yields in Thanh Hoa.

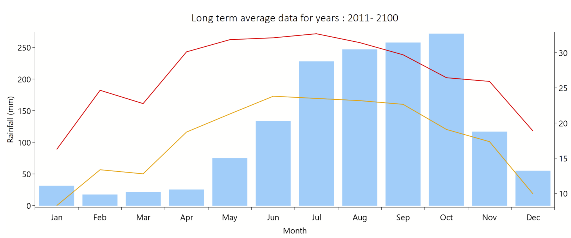


Figure 16. Long term weather for RCP 8.5

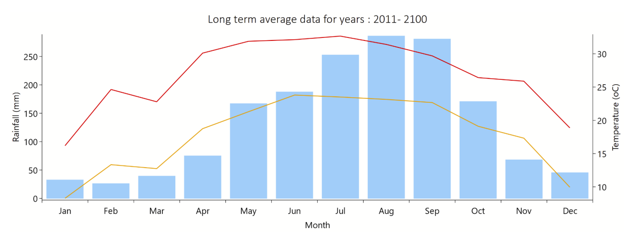


Figure 17. Long term weather for RCP 4.5

	Yield	
Month	**RCP 4.5**	**RCP 8.5**
January	260264.14	227979.89
February	222584.17	209812.68
March	226088.35	214787.35
April	225166.99	230291.79
May	216955.61	236168.28
June	226326.81	244220.70
July	238392.64	241730.23
August	257489.00	253458.24
September	277126.17	279237.45
October	288698.70	301832.64
November	299159.29	298714.78
December	301393.12	291982.04

Table 7. Total yields across different planting month

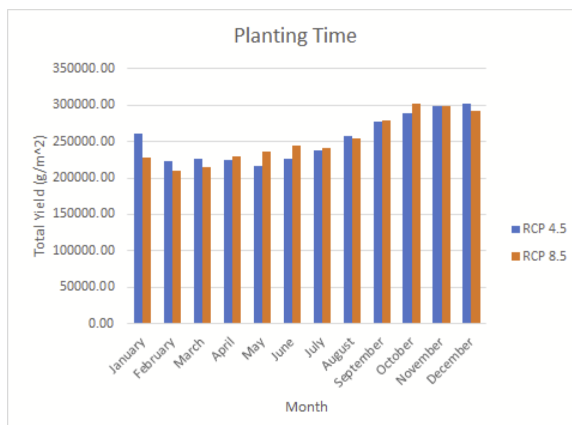


Figure 18. Total yields across different planting month

Experiment 3. Fertilizer schedule

Additionally, we focused on optimizing the fertilization schedule for sugarcane cultivation. However, due to time constraint and the large possible number of outcomes, we were unable to run simulations on all potential fertilizer schedules to maximize the yield. Nonetheless, the results obtained from the schedule change that we made were promising and showed improvements compared to the original preset of the APSIM model. Traditionally, the fertilizing schedule is divided into five stages, as follows:

1. Pre-planting: 1-2 months before sowing
2. Early growth stage: 1-1.5 months after sowing
3. Mid growth stage: 3-4 months after sowing
4. Late growth stage: 6-8 months after sowing

Based on the sowing time, our proposed schedule for fertilizing is as follows:

RCP	Planting Time	Fertilizing time			
		Pre-planting	Early growth	Mid growth	Late growth
8.5	October	Mid-August	Mid-November	Mid-January	May
4.5	December	Mid-October	Mid-January	Mid-March	July

Table 8. Fertilizing schedule

Overall, we recognized the need to differentiate between the fertilization schedule for newly planted sugarcane and the ratooning stage. The fertilizer requirements and application rates can vary depending on the stage of the crop and the mass of the sugarcane. However, we encountered challenges in implementing this differentiation using the APSIM model. This limitation is an important area for further research and development. Future studies could explore modifications or extensions to the APSIM model to better accommodate the specific fertilization needs and growth characteristics of sugarcane during both the initial planting and ratooning stages. This would provide more accurate and detailed insights into optimizing fertilizer management for sugarcane cultivation in Thanh Hoa.

Experiment 4. Plant depth

In our study, we noticed a discrepancy between the suggested planting depth by the APSIM model (150mm) and the recommendations from certain papers (ranging from 50mm to 100mm) for optimal sugarcane growth. To strike a balance, we decided to set the planting depth at 70mm for all simulations. We acknowledge that the effect of sowing depth on plant growth is an intriguing and important area for further investigation. Given the time constraints of our study, we were unable to explore this aspect in depth. Nevertheless, we recognize the potential impact of sowing depth on pest vulnerability and plant sprouting. If future research allows, it would be valuable to revisit this experiment and delve into the effects of different sowing depths on sugarcane growth. By conducting thorough experiments and monitoring the outcomes, we can gain a better understanding of the optimal planting depth that maximizes yield while minimizing pest damage and sprouting inhibition. This would contribute to a more comprehensive understanding of sugarcane cultivation practices in Thanh Hoa.

Experiment 5. Ratooning cycle

Sugarcane has the unique characteristic of being able to undergo multiple harvests (ratooning) before initiating a new sowing cycle. To explore the impact of different ratooning cycles, we conducted simulations with ratoon cycles of 2, 3, 4, and 5 years. The total yield within the time interval of 2011-2100 was recorded for each cycle. The results indicate that a ratoon cycle of 5 years yields the highest total yield for both RCP scenarios. However, when considering other important factors such as the farmers' income and the quality of sugarcane, a ratoon cycle of 5 years may not be sustainable in the long run. The extended time between harvests may lead to insufficient income for farmers during the interim periods. Additionally, older sugarcane plants tend to become lignified, which negatively impacts their quality. Considering these factors, we suggest a ratoon cycle of 2 years for both RCP scenarios. This cycle balances out the trade-off between optimizing yield and maintaining the quality of the crops. With a 2-year ratoon cycle, farmers can benefit from more frequent harvests and generate steady income. Moreover, the shorter cycle helps prevent excessive lignification of the sugarcane, resulting in better quality produce.

Year	**Ratoon Cycle**							
	RCP 4.5				**RCP 8.5**			
	2	**3**	**4**	**5**	**2**	**3**	**4**	**5**
2011-2040	45116.03	38807	47751.62	52789.12	48225.92	43397.3	54339.3	66984.5
2041-2070	15469.5	12339.99	9176.74	17050.65	23063.88	26778.68	19610.34	37568.94
2071-2100	12088.01	7776.48	8595.21	8736.23	16297.31	17390.24	25884.52	22380.52
Total	72673.54	58923.47	65523.57	78576	87587.11	87566.22	99834.16	126934
	26%	21%	24%	29%	22%	22%	25%	32%

Table 9. Total yield for different ratooning cycles

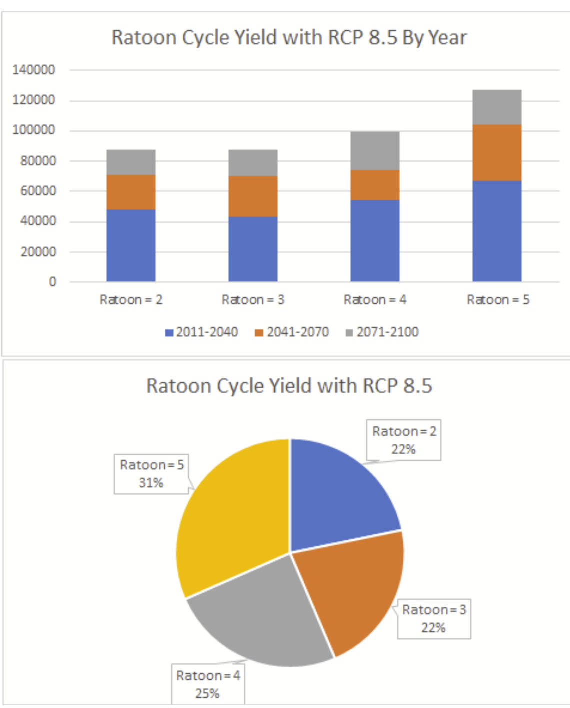


Figure 19. Ratoon Cycle with RCP 8.5

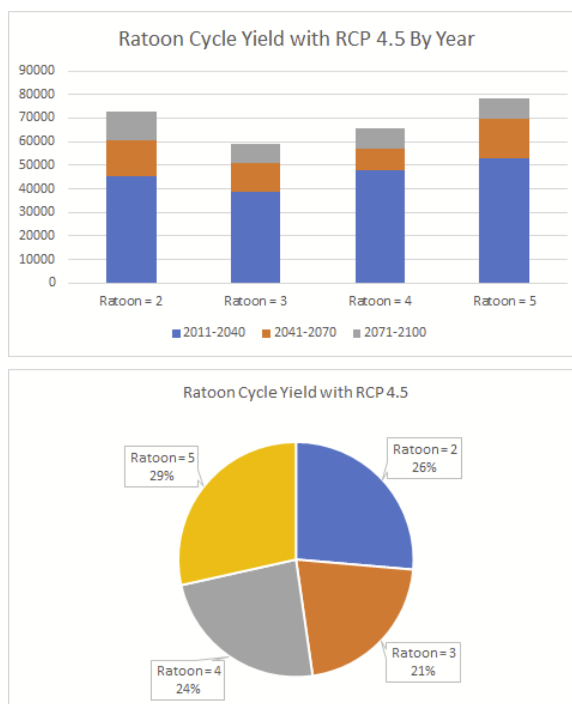


Figure 20. Ratoon Cycle with RCP 4.5

To sum up, we proposed a planting scheme as follows combined with the fertilizer schedule suggested above.

	RCP 8.5	RCP 4.5
Fertilizer	DAP	DAP
Fertilizer Amount (kg/ha)	60-180	60-180
Sowing Schedule	October	December
Plant Depth	70mm	70mm
Ratoon Cycle	2	2

Table 10. Proposed practice

We observed that the sugarcane yields for RCP 4.5 are significantly higher than RCP 8.5 after 2060, suggesting the importance of environmental factors, specifically pollution and carbon emissions, in agricultural productivity. It implies that taking measures to reduce pollution and carbon emissions can have a positive impact on the agricultural ecosystem, including sugarcane cultivation.Reducing pollution and carbon emissions can contribute to a more favorable climate and environmental conditions for crop growth, as well as improving soil health and fertility, all of which can positively influence agricultural productivity.

Comparison of Sugarcane Yield and GAEZ Data

The difference in farming practices between the medium-input approach used in current practices in Vietnam and the low-input simulations in APSIM could indeed explain the variation in yield results. The medium-input approach in farming involves a combination of manual labor and natural resources to support plant growth, which may result in different outcomes compared to the low-input approach simulated in APSIM. It is important to consider that the APSIM simulations are based on specific input parameters and assumptions, which may not fully capture the complexities and variability of real-world farming practices. However, despite these differences, we observe a similar pattern of increasing average yields across the three time periods in both APSIM and the GAEZ data.

The insignificant increase in average yield for RCP 8.5 and the more noticeable increase for RCP 4.5 align with the projected climate scenarios of each RCP. RCP 8.5 represents a more severe climate change impact, while RCP 4.5 represents a lower emission scenario with comparatively milder climate change effects. The contrasting yield patterns between the two RCPs suggest the potential benefits of adopting more sustainable practices to minimize the adverse impacts of climate change on sugarcane cultivation.

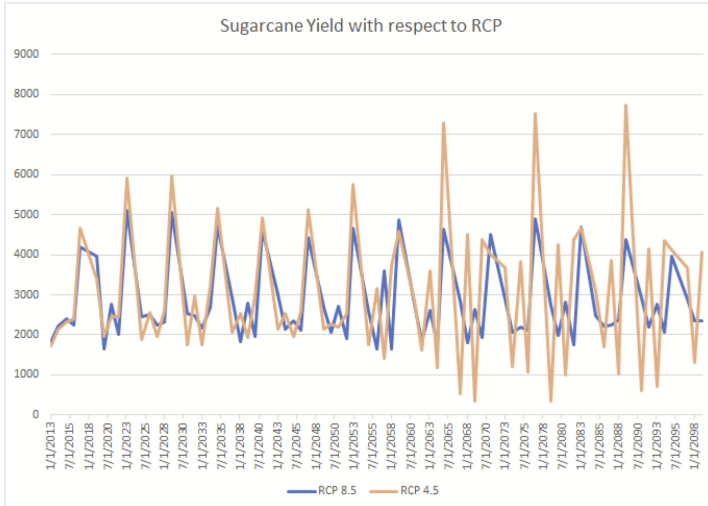


Figure 21. Total sugarcane yield between 2011-2100

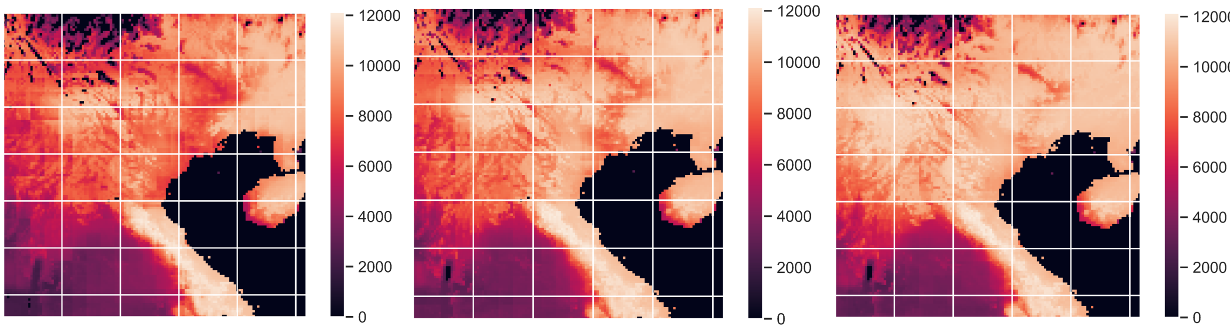


Figure 22. GAEZ data - Sugarcane RCP 4.5 Under rainfed condition

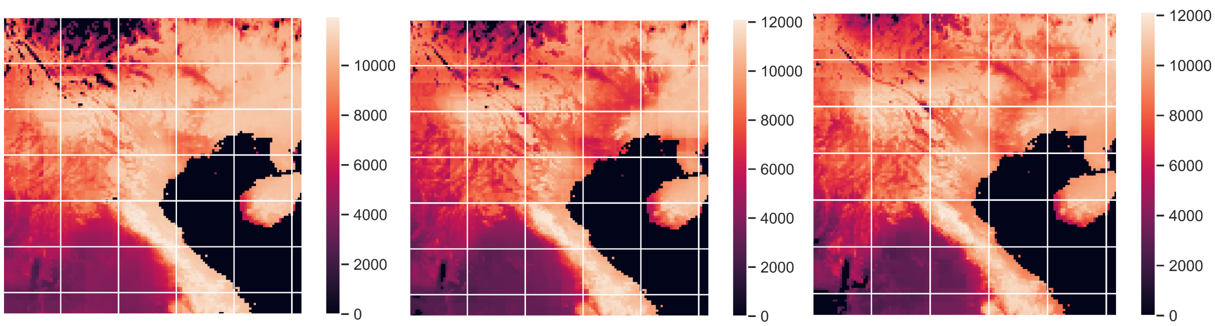


Figure 23. GAEZ data - Sugarcane RCP 8.5 Under rainfed condition

4.4 Yield, Revenue, Cost, and Profit

Cost

When assessing the farming expenses, our analysis takes into account various factors such as seed prices, fertilizers, agrochemicals, irrigation, and labor costs. However, it is important to note that our analysis focuses solely on summer cultivation for maize, while in real-world scenarios, farmers have the option to cultivate maize in spring, summer, and winter. This narrower scope of cultivation for maize in our analysis results in comparatively lower costs when compared to the other two crops.

Sugarcane, being a sensitive and long-term crop with high water requirements, necessitates increased investments in fertilizers, agrochemicals, irrigation, and labor to ensure the healthy growth of the crops. In contrast, peanuts are relatively easier to take care of and do not require substantial amounts of water. For further detailed information, please refer to the Cost_Table provided.

	Sugarcane	Maize	Peanut
	Cost (VND per year / hectare)	Cost (VND per year / hectare)	Cost (VND per year / hectare)
Seed	2,500,000	1,650,000	4,000,000
Fertilizer and agrochemicals	11,000,000	3,300,000	7,000,000
Irrigation	6,500,000	1,670,000	3,000,000
Labor	20,000,000	6,700,000	10,000,000
Total	40,000,000	13,320,000	24,000,000

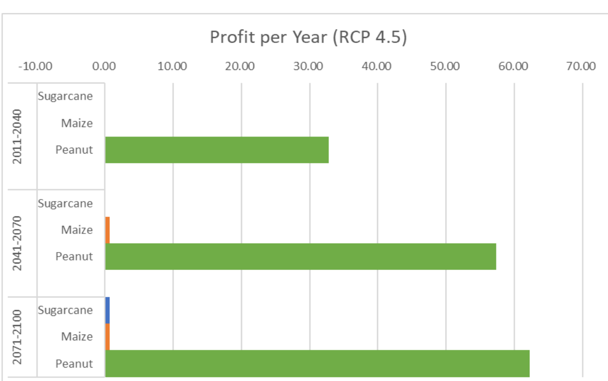
Table 11. Cost_Tabl

Profit

Upon reviewing the Profit_Table provided, it becomes evident that among the three crops, peanuts prove to be the most financially lucrative. However, it is important to recognize that the cultivation of peanuts cannot be pursued without limitations, as the dynamics of the supply-demand chain within the trading industry must also be taken into account. Nevertheless, peanuts can still serve as our primary crop, while maize and sugarcane can be considered as minor crops. With regards to maize, it is observed that under RCP 8.5, maize fails to achieve the desired yield and profitability during the periods of 2011-2040 and 2070-2100. Therefore, farmers are advised to prioritize sugarcane cultivation over maize. In the case of RCP 4.5, maize demonstrates slightly superior yields and profits compared to sugarcane within certain time ranges, such as 2011-2040 and 2040-2070. Consequently, during these periods, it would be suitable to replace sugarcane with maize as the preferred crop for cultivation.

Crop	Year Range	Yield (g/m^2)		Yield (kg/m^2)		Price (VND/kg)	Revenue per year (USD)		Total Cost	Profit per year (USD)	
		RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5		RCP 8.5	RCP 4.5		RCP 8.5	RCP 4.5
Sugarcane	2011-2040	72,018	70,698	72.0	70.7	1,350	4.14	4.06	4.13	0.01	-0.07
	2041-2070	67,982	73,738	68.0	73.7	1,404	4.06	4.41	4.30	-0.24	0.11
	2071-2100	69,813	80,731	69.8	80.7	1,460	4.34	5.02	4.30	0.04	0.72
Maize	2011-2040	9,450	12,240	9.5	12.2	3,500	1.41	1.82	1.72	-0.31	0.10
	2041-2070	10,770	15,540	10.8	15.5	3,640	1.67	2.41	1.72	-0.05	0.69
	2071-2100	9,000	14,880	9.0	14.9	3,786	1.45	2.40	1.72	-0.27	0.68
Peanut	2011-2040	43,260	60,011	43.3	60.0	14,000	25.77	35.75	2.99	22.78	32.76
	2041-2070	54,677	97,496	54.7	97.5	14,560	33.88	60.41	3.10	30.78	57.31
	2071-2100	48,661	101,428	48.7	101.4	15,142	31.36	65.36	3.10	28.26	62.26

Table 12. Profit_Table



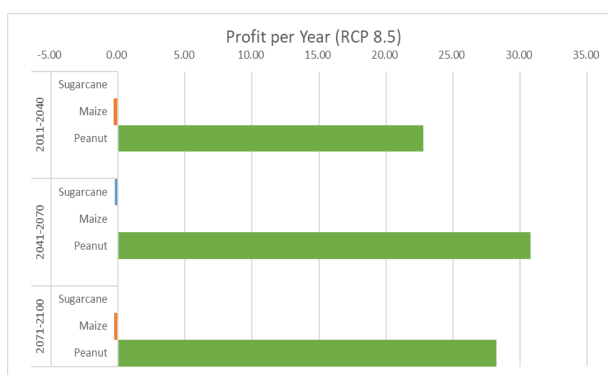


Figure 24. Profit per year(RCP 4.5)

Figure 25. Profit per year(RCP 8.5)

Recommendation for the distribution

In real-world agricultural settings, it is common for a single field to be separated into multiple sections for cultivating different types of crops. This practice allows for efficient land use and diversification of agricultural production. However, it is important to consider the dynamics of the market's supply and demand. Consequently, the feasibility of planting certain crops, such as peanuts, may vary depending on market conditions. Nevertheless, even without direct consideration of market factors, gaining an understanding of the changing trends and patterns for each crop remains valuable. This information can empower farmers to make informed decisions and make slight adjustments to their farming strategies to optimize their yields and overall productivity.

Analyzing specific scenarios for different types of crops reveals distinctive trends among farmers. By looking at [Peanut_Profit_Chart], those who own peanut farms can expect a substantial increase in peanut cultivation within the periods of 2041-2070 and 2071-2100 under the RCP 4.5 scenario. On the other hand, turning our attention to the Maize Profit Chart, farmers with sugarcane farms may experience a reduction in the proportion of sugarcane cultivation during 2011-2040 under RCP 4.5 and 2041-2070 under RCP 8.5. However, between 2071-2100 under RCP 4.5, the proportion of sugarcane cultivation is projected to increase. Upon examining the [Maize_Profit_chart], for farmers who focus on maize farming, the proportion of maize cultivation is expected to decrease only under the RCP 8.5 scenario, while witnessing a significant increase within the periods of 2041-2070 and 2071-2100 under RCP 4.5. These insights provide valuable guidance for farmers in making informed decisions regarding their crop choices and farming strategies based on projected trends and scenarios.

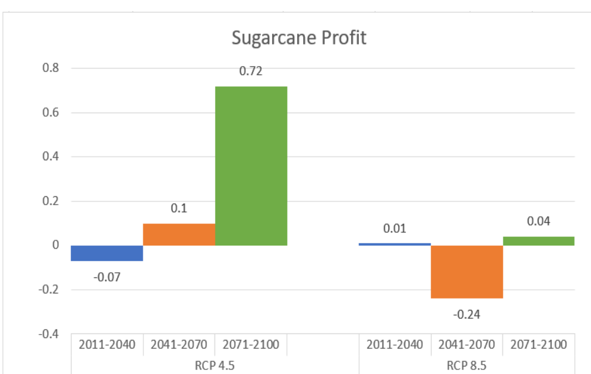


Figure 26. Sugarcane profit chart

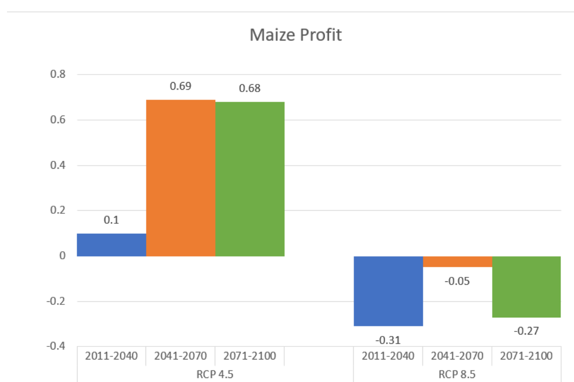


Figure 27. Maize profit chart

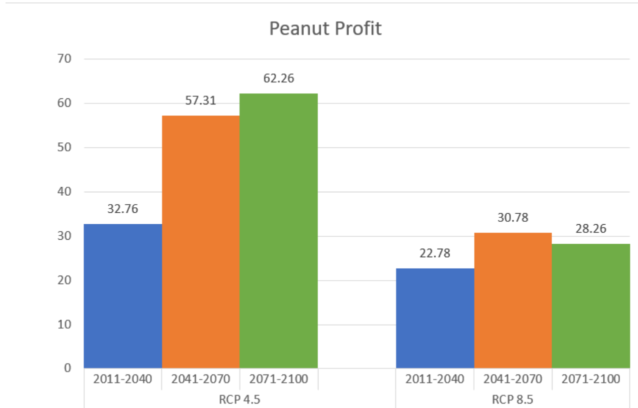


Figure 28. Peanut profit chart

The current distribution of farmland utilization among Maize, Sugarcane, and Peanuts stands at 70%, 20%, and 10% respectively. Our research and simulation indicate the possibility of making slight adjustments to the proportion of these three crops over different time periods and RCP scenarios to achieve an optimal distribution of farmland usage. For a visual representation of these changes, please refer to figures 29 to 35, which illustrate the shifting proportions of crop distribution.

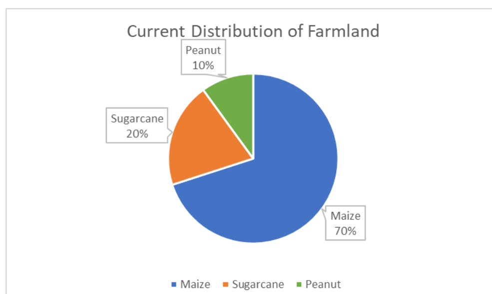


Figure 29. Current Farmland Distribution

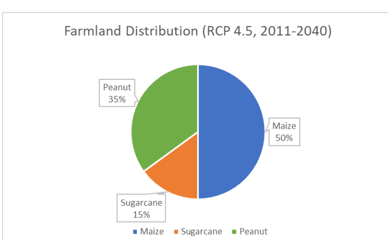


Figure 30. Farmland Distribution RCP 4.5 2011-2040

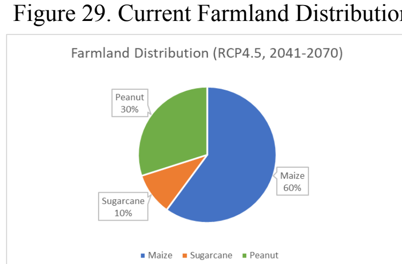


Figure 31. Farmland Distribution RCP 4.5 2041-2070

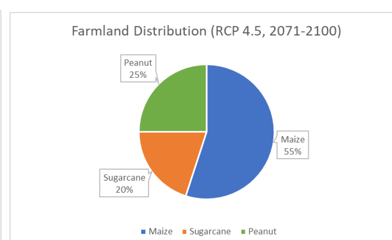


Figure 32. Farmland Distribution RCP 4.5 2071-2100

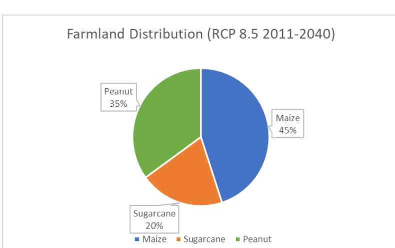


Figure 33. Farmland Distribution RCP 8.5 2011-2040

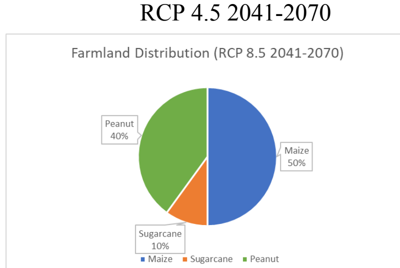


Figure 34. Farmland Distribution RCP 8.5 2041-2070

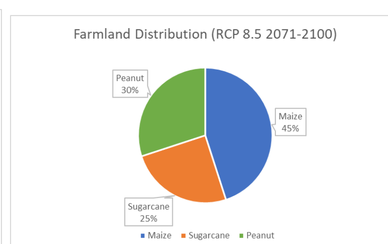


Figure 35. Farmland Distribution RCP 8.5 2071-2100

5. Limitations and Future Works

The utilization of APSIM as a simulation tool in this project encountered several limitations. Firstly, the absence of NPK fertilizer in APSIM poses a significant constraint. NPK is widely employed in Thanh Hoa for agricultural practices, yet the simulation only allows adjustments to the N to P ratio in the three crops, without enabling direct manipulation of the NPK fertilizer amount. Consequently, the simulation deviates from the actual on-field conditions, thereby compromising its fidelity. Secondly, the unavailability of certain cultivars in the APSIM simulation further hampers its accuracy. While APSIM offers a range of crop cultivars for simulation, it does not encompass widely used varieties such as LVN 10, DK 888, DK 999, LVN 20, NK 4300, or HN 88, which are commonly cultivated maize varieties in Thanh Hoa. This deficiency restricts the ability to accurately model and simulate the performance of these specific cultivars. Lastly, due to time constraints, the project could not fully explore and exploit the numerous features and capabilities offered by APSIM. However, further investigations and utilization of these untapped features can be pursued in future endeavors to enhance the comprehensiveness and efficacy of the simulation.

6. Conclusion

The simulation results using APSIM were limited by the fact that the simulation was conducted with data collected over the Internet rather than actual data. However, we were able to identify large trends based on soil and climate data. From these simulation results, we were able to make two conclusions. The first is the need to dynamically change the rate of grain production in response to climate change. The profitability of agricultural actors is an important factor in their participation in agricultural activities. The more actors involved in agricultural production, the more stable the food chain. Therefore, they need to think about how to maximize their profits, and one way to do this is to grow crops that have the best economic returns based on the climate. In our simulation results, sugarcane is expected to increase in production over time, the peanut is expected to remain the same in production, and maize is expected to decrease in production. Therefore, in order to maximize economic returns, grain cultivation should be organically adapted to climate change. Second, the simulation results show that the amount of maize, a common staple food grain, is expected to decrease with climate change and responses such as increasing the cultivation of other crops that can be utilized as staples will be needed. Staple food crops such as rice and maize are relatively critical for food ecology. The production of maize, the second most commonly grown staple food crop, was declining in both the RCP 4.5 and RCP 8.5 scenarios. Therefore, it will be necessary to identify crops that can be utilized as staple foods and increase their production in response to climate change, and to increase their production.

7. Reference

[1] Dinh Thao, T., Tri Khiem, N., Xuan Trieu, M., Gerpacio, R. V., & Pingali, P. L. (2004). Maize in Vietnam: production systems, constraints, and research priorities. CIMMYT.
[2] Baruah, S., & Mohanty, S. (2019). Identifying opportunities and challenges for creating a climate-smart food system in Vietnam.
[3] Pokhariyal, S., & Govind, A. (2022). Spatiotemporal drought analysis and crop modeling to decipher risks and adaptation strategies in Ethiopia.

[4] Tuong, L. Q., et al. (2019). Effect of different planting densities and fertilizer rates on corn yield and yield components under Northern Vietnam growing conditions. Ecology, Environment and Conservation, 25(4), 1696-1702.