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Research Article
Crop Calendar Shift as a Climate Change Adaptation Solution for Cassava Cultivation Area of Binh Thuan Province, Vietnam

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Abstract

Background and Objective: Binh Thuan Province is one of the large cassava cultivation areas in Vietnam. However, in recent years the cassava crops are facing the increased risks of irrigation water shortage due to drought and abnormal change of rainfall under the impacts of climate variability (ICV), leading to reduce crop yield. The study was, therefore, conducted to define a suitable period for planting cassava crops in Binh Thuan Province, Vietnam to reduce the negative impacts of weather factors. **Materials and Methods:** The study was conducted using the AquaCrop model to predict the cassava yield corresponding to different crop calendars to define the suitable planting period. The model performance was appraised through the calibration and validation process with the index of agreement (d), correlation coefficient (r) up to 0.80 and RMSE lower than 0.40. **Results:** The results carry out that the cassava yield can be reached 48.18 t ha^{-1} if the crop calendar (CC) is early shifted from 14-21 days compared with the current crop calendar (CCC) for spring crop while an increase of approximately 5.16% can be achieved if the CC is delayed from 7-14 days for summer crop season. The results stated that the proposed model is suitable for defining the CC based on its simulated biomass and cassava yield. **Conclusion:** The study indicated that rainfall plays an important role in the planting calendar of cassava crops. Through, it is also confirmed that planting calendars of cassava crops is not appropriate for current weather conditions.

Key words: Crop model, off-seasonal rainfall, biomass, index of agreement, crop calendar

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent years, climate variability has seriously affected the aspects of human life[1,2]. Among the affected sectors, agricultural is considered as the most vulnerable[3,4]. A study on the ICVs on cassava yields in the Togo area by Boansi[5] reported that agricultural production in developing countries is facing the potential risks. A study on the climate variability scenarios and sea-level rise for Vietnam by MNRE[6] reported that Vietnam is one of the top countries which will be severely affected by climate variability, resulting in the more frequent occurrence of drought, off-season rainfall and flooding. Emaziye[7] reported that rainfall is considered as the main factor which will be seriously impacted by changes in climate parameters. According to Vongcharoen *et al*.[8], the changing in rainfall trends due to the ICVs, resulting in the shifting in water use demand and cropping calendar. A study by Ropo and Ibraheem[9] on the ICVs on the cassava yield in Port Harcourt of Nigeria reported that the rainfall has a significant influence on the cassava yield in the study area.

In Vietnam, cassava is the third rank with an area of over 5.0 million ha and yield achieves[10-12] over 1.0 Mt. Cassava is widely planted in Binh Thuan Province and is considered as the main plant to help improve the income of local poor people and ethnic minorities[12,13]. An advantage of cassava is easy to plant, tolerate poor soil, less care, low cost and easy to harvest[7,14]. Also, it has a low risk and serves as a potential feedstock for the use of starch for pharmaceutical, bioethanol, animal feed and biofilm textile[4,15]. Especially in the context of humanity seeking fossil-fuel alternatives to restricting global warming[10,13]. In the study area, farmers often plant cassava cutting based on irrigating water only comes from local rainfall[11,12]. According to Janket *et al*.[16], one of the biggest challenges is the scarcity of water for irrigation due to drought and off-seasonal rainfall under the ICVs. Howeler[10] exported that cassava plant is playing a key role for life when the world's population is growing and clean fuel source are, therefore, requiring more and more compared to ever[16-18]. As a recognition of the ICVs on cassava in many areas in the world, studies on cassava yield in the context of climate variability have been carried out by Fermont *et al*.[14] or East Africa area, by Emaziye[7] for Delta State of Nigeria, by Janket *et al*.[16] for Thailand, by Mai[12] for Phu Yen Province of Vietnam. Studies on the ICVs on irrigation water demand for cassava crops reported that the CC plays an important role in mitigating the lack of irrigation water and reducing the crop yield[12,19,20]. A study on the ICVs on harvest time of cassava crops conducted by De Oliveira *et al*.[19] reported that the determination of the suitable times for planting cassava crops is needed to mitigate the negative impacts of weather factors on the crop yield. Another study on growth rates and yields of cassava at different planting calendars by Phoncharoen *et al*.[20] stated that crop yield is strongly dominated by the CC. The determination of the right time to plant the cassava crops is considered as an effective solution to reduce the unwanted ICV and obtain the optimal yield. The main aim of this study, therefore, was to find a suitable time to plant for cassava crops in Binh Thuan Province to reduce the negative impacts of weather factors and optimal the crop yields.

MATERIALS AND METHODS

Study area: Binh Thuan is a Province belonging to the South-central region of Vietnam, located at 10°33'42"-11°33'18"N and 107°23'41"-108°52'18"E (Fig. 1). Binh Thuan Province is mainly low hills, narrow coastal plains, narrow horizontal terrain along with the northeast-southwest and was divided into 4 main terrain types including sandy soil and coastal sand dunes, alluvial plain, hilly areas and low mountainous areas[12,13].

The study area is one of the large cassava planting areas next to Phu Yen, Quang Ngai and Binh Dinh Provinces of Vietnam[3,12]. The climate is divided into two distinct seasons including dry and wet seasons. The wet season usually starts from May to October and the dry season is from November to April with average temperature 27.3°C and annual rainfall varied from 1473-2138 mm with 80% of rainfall focused in the wet season while rest 20% concentrated in the dry season[12,21].

AquaCrop model description: The AquaCrop is a crop model that constructed by Food and Agriculture Organization (FAO) for defining water use requirement, establishing irrigation schemes, predicting crop yield under different weather conditions[22-24]. The AquaCrop model is developed based on balance criteria between simplicity, accuracy and robustness with a combination of four main modules including climate, crop, soil andmanagement[22,23]. Detailed information about the AquaCrop model can be seen in FAO[23].

Input data: To conduct this study, the input climate data including temperature, solar radiation, wind, humidity and precipitation are firstly required and were collected from the Hydrometeorological Forecasting Centre of Binh Thuan Province in the period of 2010-2019 (Fig. 2). Then, other input data for crop module such as dates of emergence, canopy cover, canopy growth coefficient, minimum and maximum root depths, canopy decline coefficient, transpiration crop coefficient, root expansion shape factor, reference harvest index, lower and upper leaf growth threshold are presented in Table 1.

Fig. 1: Map of the study area

Table 1: Key parameters used in the AquaCrop model

Parameters	Values: Default	Values: Optimal	Sensitivity level
Base temperature (°C)	9.00	10.000	Low
Cut-off temperature (°C)	30.00	28.000	Low
Maximum root extraction at the top (m^3/m^3/day)	0.03-0.06	0.046	Low
Maximum root extraction at the bottom (m^3/m^3/day)	0.001-0.06	0.038	Low
Canopy cover per seedling at 90% emergence (cm^2/plant)	10.00	8.900	Moderate
Canopy growth coefficient (%/day)	11.80	11.500	High
Maximum canopy cover (%)	99.00	87.000	Moderate
Maximum rooting depth (m)	1.70	1.200	Low
Canopy expansion shape factor	2.50	2.300	Moderate
Early canopy senescence p (TAW (%))	0.70	0.600	Moderate
Early canopy senescence shape factor	2.50	2.400	High
Normalized water productivity (g m^{-2})	15.00	14.000	High
Reference harvest index (%)	40.00	37.000	Moderate

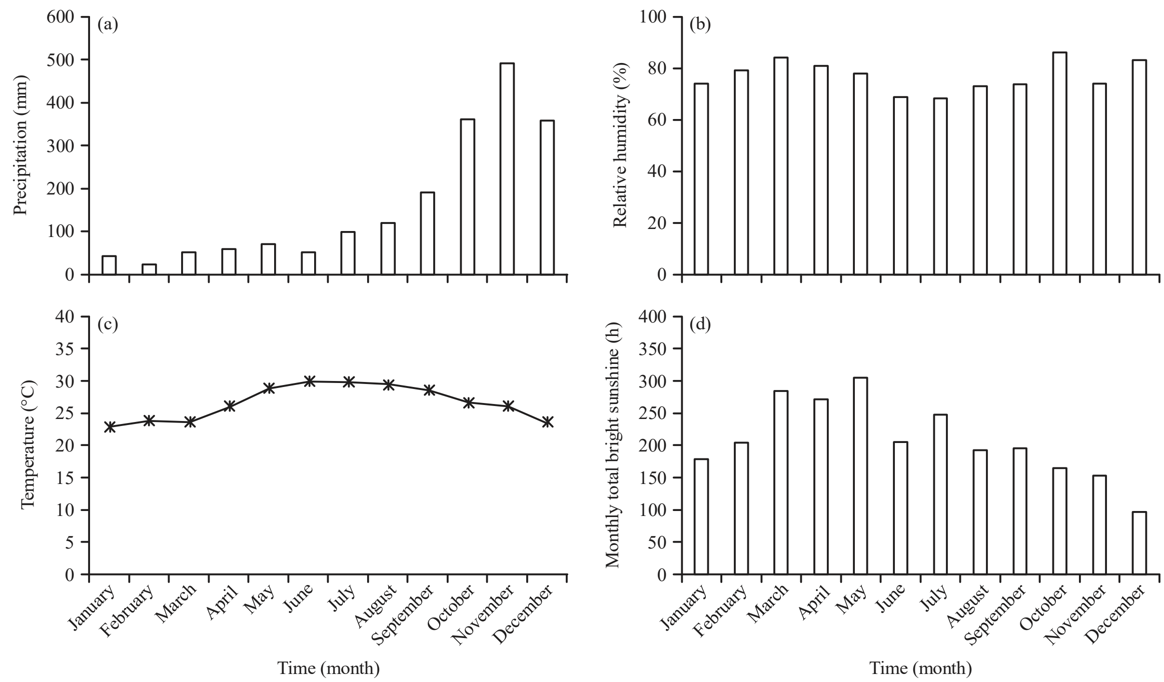

Fig. 2(a-d): Illustration of input climate data for simulating the proposed model, (a) Precipitation (mm), (b) Relative humidity (%), (c) Temperature (°C) and (d) Monthly total bright sunshine (h)

Table 2: Detail information about crop calendar and fertilizer rate for cassava crops

Crops	Crop calendar		Sowing density	Fertilizer rate (kg ha^{-1})			
	Plant	Harvest	(No. of cuttings ha^{-1})	NPK	Urea	Kali	Manure (t)
Spring season	10-May	05-July	15870	150	120	100	8
Summer season	30-March	20-February	13400	130	120	80	8

Table 3: Soil characteristics analyzed at the study area

Soil description	Values
Permanent wilting point (vol%)	8
Total amount of water (mm/m)	80
Field capacity (vol%)	16
Volumetric water content at saturation (vol%)	38
Saturated hydraulic conductivity (mm/day)	2200
Curve number	46

In the study area, KM94 cassava variety is sown up to 60% of the are awhile the remaining 40% is KM98-5 varieties[12,13]. An advantage of KM94 variety is that high yield and less pest infestation with growing cycle changed in the period of 9-13 months depending on each crop season and each year[12,13]. The detail information about crop calendar, sowing density, fertilizer rates of cassava crops showed in Table 2. Cassava cuttings are sowed with row spacing of 9.0×0.7 m during the 2nd week of May and harvested during the 3st week of July in the next year for spring crop while for summer crop, cassava cuttings are sowed with row spacing of 0.9×0.8 m during the 4th week of March and harvested during the 3rd week of February in the next year.

Fertilizer was applied at the recommended amount of approximately 8 t ha^{-1} manure, 150 kg ha^{-1} N, 120 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} K_2O, respectively for spring crop while the correspond values of summer crop are 8 t ha^{-1} manure, 130 kg ha^{-1} N, 120 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} K_2O, respectively. For the soil module, the soil features were collected at the represent locations in the field and samples are, then, analyzed applying the soil water characteristics program[25]. The results show that the soil in the study area was sandy loam to silt loam with pH = 5.4-5.9. The soil components include potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) are 1.35, 0.58 and 0.34 meq kg^{-1}, respectively. Based on the ideal and root restricting bulk densities for soil-water contents allocated by FAO[5] and soil characteristics analyzed are presented in Table 3.

Evaluating the model performance: The performance of the proposed crop model was assessed based on comparing measured and simulated biomass and cassava yields for both spring and summer crop seasons in the period of 2010-2019. The statistical indices namely the root mean square error (RMSE), the index of agreement (d) and correlation coefficient are used to assess the model performance.

The RMSE is given as follow[21,26]:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(M_i - S_i\right)^2} \tag{1}$$

The index of agreement (d) is defined as follow[21,22]:

$$d = 1 - \frac{\sum_{i=1}^{N}\left(M_i - S_i\right)^2}{\sum_{i=1}^{N}\left(\left|M_i - \overline{M}\right| + \left|S_i - \overline{M}\right|\right)^2} \tag{2}$$

where, M and S in the Eq. 2 are the measured and simulated data and n is the number of data points while is average value of measured data.

RESULTS AND DISCUSSION

Sensitivity analysis: Results of sensitivity analysis pointed out that cassava yield was highly sensitive to canopy growth coefficient, early canopy senescence shape factor, normalized water productivity while maximum canopy cover, canopy expansion shape factor, early canopy senescence and reference harvest index were moderate sensitivity and other parameters include base temperature, cut-off temperature and maximum root extraction at the top and bottom recorded a low impact to crop yield (Table 1). When a model is applied to a practice problem, it is necessary to find the optimum values of the main parameters[1,18].

Model performance evaluation: According to Abedinpour *et al.*[22] the performance of the model is assessed satisfactorily when the r and d values are more than 0.5 and the RMSE value approaches zero. The analyzed results carried out that the simulated yield is a good fit with the measured yield with d = 0.82-0.88, RMSE = 0.26-0.34 and R^2 = 0.83-0.92, respectively for both spring and summer crop. The results confirmed that the proposed crop model is good suitable for simulating biomass and cassava yield in the study area (Table 4).

Relationship between crop calendar and yield: In Binh Thuan Province, cassava cuttings are often sowed based on the experience of farmers[12,20]. According to Lee and Dang[26], climate variability has strongly impacted on the weather factors including air temperature, rainfall and evaporation, leading to the water use requirement is also changed and CCC is no longer appropriate[12,20], resulting in the reducing of crop yield. Therefore, this study is conducted by backward and forward of CC from 7-35 days compared to the CCC for purposing the optimal productivity. The simulated results carried out that yield of spring and summer cassava crop has changed significantly after CC shifted from 7-35 days compared to the CCC (Fig. 3a, b).

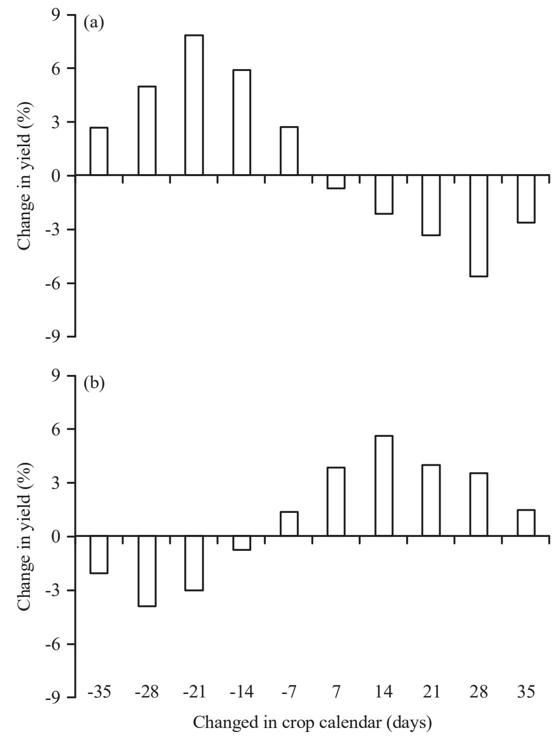

Fig. 3(a-b): Change in cassava yield after shifting crop calendar of (a) Spring crop and (b) summer crop

Table 4: Model performance assessed through the d index and RMSE

Type of yield	Crops	Validation period (2013-2018) d	RMSE	R^2
Biomass	Spring	-	-	-
	Summer	-	-	-
Fresh tubers	Spring	0.88	0.26	0.92
	Summer	0.82	0.34	0.83

Specifically, the cassava yield can be achieved 44.57 t ha^{-1} (increased approximately of 7.89%) when the CC of spring crop is backwardly shifted 21 days compared to CCC whereas, a decreased trend varied from 0.73-5.64% was recorded when the CC is forwardly shifted from 7-35 days compared to CCC. For summer crop, the cassava yield only can be increased 5.89% when the CC is delayed 14 days compared to the CCC whereas, a decreased tendency of yield varied from 0.78-3.92% was also found when the CC was backwardly shifted 7-35 days. Generally, the simulated crop calendar change scenarios for both spring and summer crops pointed out that the change in the CC can lead to a significant increase in cassava yield compared to the CCC.

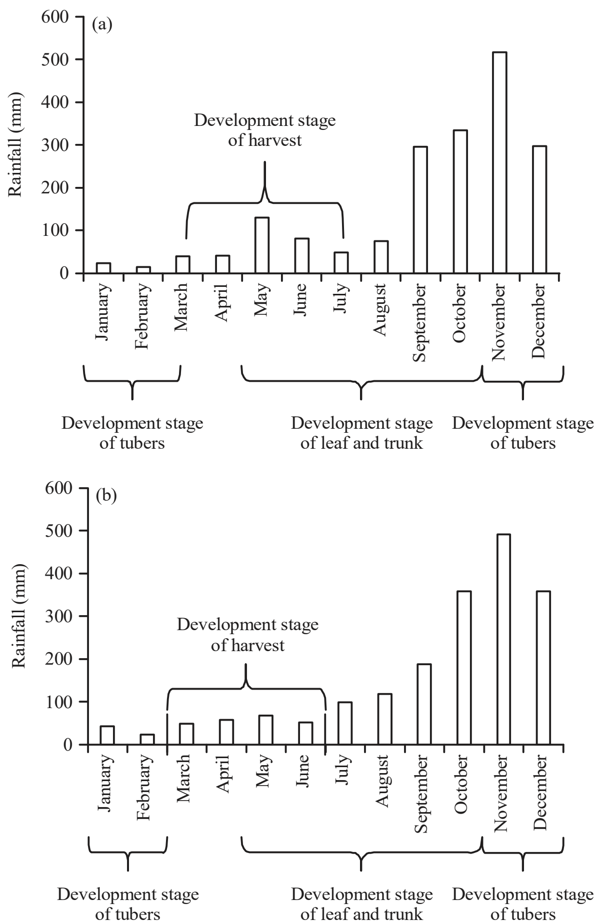

Fig. 4(a-b): Relationship between (a) Current crop calendar of spring crop with rainfall in the period of 2000-2015 and (b) Shifted crop calendar in the period of 2016-2019

Relationship between crop calendar and rainfall: The analyzed results of rainfall carried out that yield of spring cassava crop will achieve an optimal value if the CC is advanced from 14-21 days compared with CCC. The results are suitable with the statistical analyses of collected rainfall data series in the entire study area. The results showed that the development stage of cassava tubers of spring crop coincides with a stage lasting no rainfall, resulting in water stress. The lack of irrigation water in the development stage of cassava tubers may be one of the main reasons for the under development of cassava crop. However, if the CC of spring crop is advanced from 14-21 days, development stage of cassava tubers will be picked up the high rainfall stage, leading to good growth of cassava and its tubers (Fig. 4a, b).

A study on the response of cassava yield to the spatial scale variation of rainfall in Port Harcourt by Ropo and Ibraheem[9] confirmed that rainfall plays an important role in the growth of cassava and its yield. The analyzed results of the relationship between the CCC of spring and summer crops with rainfall shows that the harvest stage of both spring and summer crops in the study area coincides with the dry weather stage which is very convenient for harvesting operation and contributing to reduce crop losses. Change in the crop calendar can help to get a dry weather condition towards the end of the crop season, suitable for harvesting of crop.

CONCLUSION

The study was executed to detect the proper time for planting the cassava crops across the cassava cultivation area of Binh Thuan Province of Vietnam under the impacts of climate variability. The results pointed out that the proposed crop model is suitable to study the crop calendar shift with the values of both d index and R^2 up to 0.80 while RMSE less than 0.40, respectively.

The results pointed out that the shifting from 7-14 days for summer crop is perfectly suited to the current features of local weather condition in the study area to achieve the optimal productivity. The simulated cassava yield can change in a positive way when the crop calendar is shifted the backward and forward compared to the current crop calendar for both spring and summer crops.

SIGNIFICANCE STATEMENT

This study discovers the climate change impacted on the local weather factors, resulting in changes in the crop planting calendar season of the cassava cultivation area in Binh Thuan Province of Vietnam. The researched results stated that the FAO-AquaCrop model is a suitable tool to study on the crop growing in current weather conditions as well as future climate change scenarios.

This study will help authorities as well as farmers to understand the negative effects of adverse weather conditions as well as optimize crop yield in the context of climate change. Thus, a new FAO-AquaCrop model applies for other regions on the world may be arrived at.

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