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Assessing climate risk to cassava (*Manihot esculenta*) yield based on rainfed

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ABSTRACT

Sowing of cassava is frequently encountered with lack of irrigation water due to the occurrence of meteorological drought, resulting in the decline of yields or even complete crop failure. This research was examined during 2000 to 2019 based on the CropWat model to predict cassava yield in the cultivation regions of Tanh Linh district in the context of climate change (CCC). The performance of applied model was valued based on the climate data, soil and crop management during the studied period. The valued results stated that error indices (RMSE = 0.26 ÷ 0.34, R^2 = 0.83 ÷ 0.912 and d = 0.78 ÷ 0.88) proved the CropWat model's efficiency for simulating cassava yield across the study area. The simulation showed that the optimal cultivation entrance (OCE) varied from 5th to 22nd April, when the cassava yield achieved up to 46.4 ton per ha for spring crop and 42.3 ton per ha for summer crop from 17th to 24th of April. The results indicated that precipitation strongly influenced the cultivation processes as well as cassava yield in the study area. Based on the finding, it can be stated that cultivation seasonal of main cassava crops is not suitable to the weather conditions. In general, farmers need to alter in the cultivation seasonal to minimize the adverse effects of precipitation factor as well as contribute to improve crop yield.

Key Words : *Manihot esculenta,* cassava, climate change, CropWat, entrance, rainfed

INTRODUCTION

Cassava (*Manihot esculenta* Crantz.) is known as a main plant in Tanh Linh District to improve the lives of local people and especially ethnic minorities (Pham *et al.*, 2001; Le *et al.*, 2019). Climate change has strongly impacted the cassava planting paddies in the study area and cassava crops grown as rainfed are facing the potential challenges (Pham *et al.*, 2001; MNRE, 2016). In recent years, the cassava paddies in Tanh Linh district have regularly faced the lack of irrigation water due to drought, resulting in reduce crop yield as a part of climate change (Labarta *et al.*, 2017; Janket *et al.* 2018). In the study area, cassava plants were sown based on irrigation water provided from precipitation (Le *et al.*, 2019). In 2016, MNRE stated that Vietnam will strongly be impacted by climate change and the drought and unusual precipitation off-season tend to increase in frequency and intensity in the future. Boansi (2017) conducted a study on the impacts of climate change (ICC) on cassava yield in the Togo Area and reported that agricultural sector is facing higher risks of climate change. Janket *et al.* (2018) reported that the potential challenges of developing nations are the lack of irrigation water in the dry season, lead to reducing the crop yield.

Climate change is assessed as one of the enormous challenges facing humanity in the 21st century, studies on the ICC on the plant yield have been carried out in Africa (Mbanasor *et al.*, 2015; Boansi, 2017; Janket *et al.*, 2018), Asia (Alene *et al.*, 2018; Phoncharoen *et al.*, 2018; Janket *et al.*, 2018; Vijayalakshmi *et al.*, 2020) and Vietnam (Kim *et al.*, 2009; Khuc *et al.*, 2012; Labarta *et al.*, 2017). Specifically, Mbanasor *et al.* (2015) studied the ICC on the cassava yield in Nigeria and reported that there is no significant impact by the recent impressions of climatic change on the cassava yields in the study area. Boansi (2017) evaluated the impacts of climatic and non-climatic factors on cassava yields in Togo and reported that investment in low-cost irrigation water is suggested to enhance the practice of supplemental irrigation. Janket *et al.* (2018) conducted a study on the seasonal variation as a part of climate change on cassava genotypes in a tropical savanna climate. Their results carried out that the OCE for cassava crops contributed the largest portion of crop yield. They also stated that the results will be useful for selecting suitable cassava genotypes for different sowing seasons for high-quality cassava in the future. In Vietnam, Le *et al.* (2019) conducted a study on the characterizations of cassava in Vietnam and reported that approximately of 95% households in the surveyed regions has stated that the changing in weather patterns as such hot summer, decline in precipitation in the wet season and longer periods of droughts over the last ten years is noticed. In addition, the ICC was evaluated as top concerns by cassava farmers both in terms of actual impacts and perceived influence. Based on these facts, this study was conducted to assess the risks of rainfed on the growth process in Tanh Linh district, to minimize the unwanted impacts of rainfed factor on cassava yield in the study area.

MATERIALS AND METHODS

Description of the Study Area

Tanh Linh is a mountainous district in the northwest of Binh Thuan province, Vietnam, located at 10°50'24"-11°20'56"N, 107°30'50"-107°51'21"E (Fig. 1). Tanh Linh covers a land area of 1,174 km^2 with four main terrain types *viz.*, sandy soil and coastal sand dunes, alluvial plain, hilly areas and low mountainous areas (Kim *et al.*, 2009; Labarta *et al.*, 2017). The climate is in a transitional nature between the precipitation regime of the south-central coast and southern delta. In other hands, climate is the buffer zone between the heavy precipitation center of the Di Linh Plateau and the coastal plain (Pham *et al.*, 2001). However, the climate still splits in two distinct seasons called the rainy and dry seasons with the rainy season lasts from May to November and crops planted during this period. While the dry season lasts from December to April and this period do not grow as well, and high temperature and less rainfall have a great disadvantage on crop yields. Average annual temperature 27°C and precipitation about 1,000 mm with 85% of focused in the wet season (Kim *et al.*, 2009; Pham *et al.*, 2011).

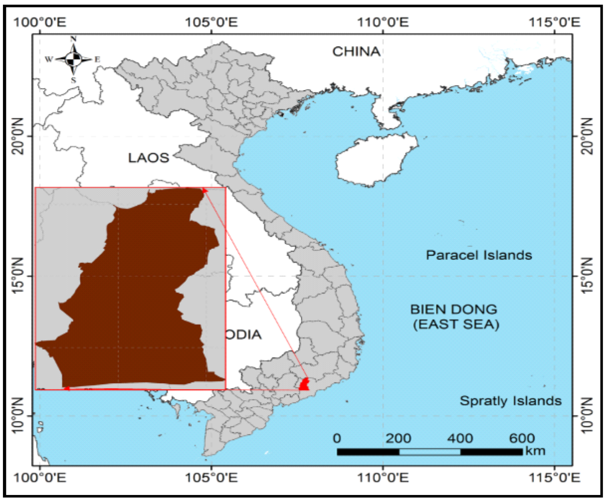

Fig. 1. Map of the study area.

CropWat Model Description

The CropWat is a crop model that was developed by Food and Agriculture Organization (FAO, 1992) for establishing the water use requirement, irrigation diagrams to achieve the optimal crop yield in the different climate conditions (Shah *et al.*, 2015; Zoidou *et al.*, 2017). In addition, CropWat model allows to run simulation irrigation practices, irrigation schedules under different irrigation conditions (Adeniran *et al.*, 2010; Banik and Ranjan, 2014). The model operates based on running simulation for main modules climate, crop, soil and management (Shah *et al.*, 2015; Zoidou *et al.*, 2017). Detailed information about the CropWat model are given by Banik and Ranjan (2014).

Input Data

The CropWat model was designed based on the relationships between the soil-plant and atmosphere system (Bouraima *et al.*, 2015; Shah *et al.*, 2015). Its' performance is thus carried out through detail information on climate, soil, cultivar and management practices (Shah *et al.*, 2015; Zoidou *et al.*, 2017). For conducting the climate module, the weather data such as temperature, relative humidity, wind speed, solar radiation, sunshine duration and rainfall/precipitation are required (Fig. 2). The soil in the area is golden brown. The physical and chemical characteristics of experimental area were obtained based on samples collected at the marked observation points before the shoots were sown. The soil samples were then analyzed applying the Soil Water Characteristics Software, which indicates a sandy loam to silt loam composed by 32% of coarse sand, 35% of sand and, 17% of silt and 16% of clay. Based on the ideal and root restricting bulk densities for soil-water contents includes the permanent wilting point equal 8%, the total amount of water equal 80 mm per meter, field capacity equal 16%, volumetric water content at saturation equal 38%, saturated hydraulic conductivity 2.2 m per day and curve number equal to 46.

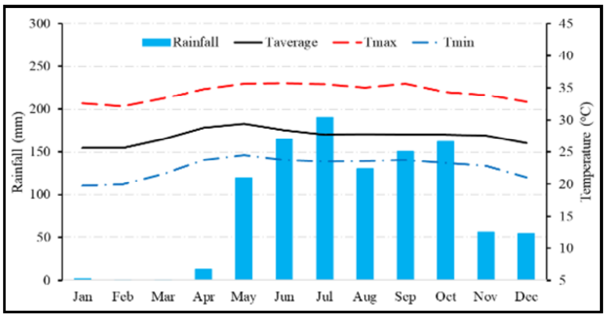

Fig. 2. Illustration of input climate data for simulating the CropWat model.

In the study area, cassava variety KM98-5 is popularly sown (Pham *et al.*, 2011; Le *et al.*, 2019) due to its' high productivity, less pests attack and short life cycle (Kim *et al.*, 2009; Labarta *et al.*, 2017). Fertilization rates were recommended by the Department of Agriculture and Rural Development (DARD) with an amount of approximately 8 t/ha manure, 150 kg N/ha, 120 kg P/ha and 100 kg K/ha for spring crop before and 30 days after sowing, while the summer crop was fertilized with 6 t/ha manure, 130 kg N/ha, 120 kg P/ha and 80 kg K/ha. The detail information about crop calendar, sowing density, fertilizer rates of cassava crop is given in Table 1.

RESULTS AND DISCUSSION

Model Performance

The index of agreement (d), root mean square error (RMSE) and the correlation coefficient are the statistical errors which are commonly used to evaluate the performance of proposed model. In general, the performance of the CropWat model showed a good efficiency based on comparing between the simulated and observed cassava yield for both spring and summer crops. The model calibration and validation achieved a high correlation with d = 0.78-0.88, RMSE = 0.26-0.34 and R^2=0.83-0.92, respectively for both spring and summer crops (Fig. 3). Specifically, the calibrated results carried out a good correlation between the simulated model and observed cassava yield for both spring and summer crops, with d = 0.78-0.82, R^2 = 0.84-0.89 and RMSE = 0.29-0.33, respectively (Fig. 3a). Similarly, the validated results pointed out a good fix between the simulated results and observed cassava yields with d = 0.82-0.88, R^2 = 0.83-0.92, and RMSE = 0.26-0.34, respectively for the spring and summer crops (Fig. 3b). The compared results of the high values of d and R^2 and low value of RMSE affirm that the CropWat model demonstrates a good suitable for simulating cassava yield in the study area.

Climate Risks Analysis

The potential yield of the spring crop cassava can be decreased from 0.8 to 3.9% compared to the average cassava yield if the sowing is shifted from 2 to 4 weeks earlier (Table 2). On the other hand, the cassava yield of the spring crop recorded a downward trend for sowing conducted from 2nd to 16th December and a significant reduction for sowing conducted on the end of November and the onset of December (Fig. 4a). While cassava yield of the summer crop can be reduced down to

Table 1. Crop calendar and crop growth stage coefficient (KC) for cassava sowing crops.

Crop	Crop coefficient (KC)				Fertilizer rate (kg/ha)				Cuttings density (cutting/ha)	Crop length (month)	Sowing date	Harvest date
	LP	I	D	L	N	P	K	Manure				
Spring	0.40	0.60	1.15	0.80	150	120	100	8	15870	10	31-Jan	30-Nov
Summer	0.35	0.55	1.10	0.70	130	120	80	6	13400	12	01-May	30-Apr

LP : Land preparation stage, I : Initial stage, D : Development stage, M : Mid-season stage, L : Late season stage.

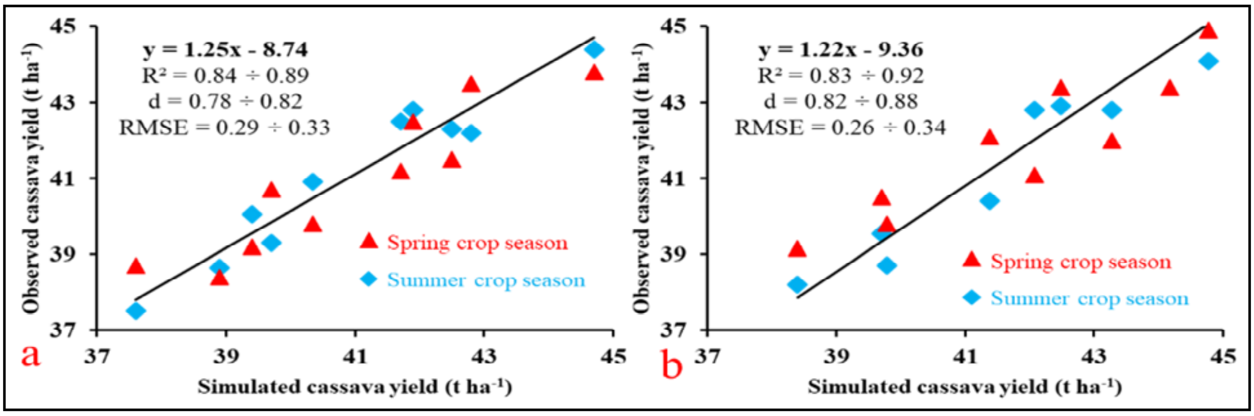

Fig. 3. Comparison of simulated model and observed cassava yield for spring and summer crop with (a) Calibration process (2000-2009) and (b) Validation process (2010-2018).

Table 2. Cassava yield of the main sowing crops simulated applying the CropWat model

Period of sowing	Spring crop		Period of sowing	Summer crop	
	Crop yield (t/ha)	Rate of change (%)		Crop yield (t/ha)	Rate of change (%)
Current	43.8	-	Current	39.2	-
06-Feb	45.7	+ 4.5	22-Apr	41.4	+ 5.7
13-Feb	45.4	+ 3.8	15-Apr	42.3	+ 7.8
20-Feb	46.4	+ 5.9	18-Apr	41.0	+ 4.8
27-Feb	44.9	+ 2.7	11-Apr	40.7	+ 3.9
03-Mar	44.3	+ 0.5	04-Apr	39.8	+ 1.7

1.2 to 4.3% compared to the average cassava yield if the sowing is delayed from 3 to 4 weeks (Fig. 4b). Generally, the sowing of spring and summer crop seasons in the study area is not suitable to the current weather conditions.

Rainfed is an important factor for cassava production in the study area because it is the main source of irrigation water and thus any change in precipitation occurred during the life cycle of cassava will directly impact the growth process as well as cassava yield. The analysis revealed that cassava yield of the spring crop can be achieved an optimal yield if the sowing is delayed from 3 weeks compared to the current sowing (Fig. 5a). The results are suitable with observed precipitation data in the entire study area. Specifically, the development stage of the tuber of spring crop coincides with periods of appeared precipitation. An abundance of irrigation water in the development stage of tuber may be one of the main reasons for entrancing the optimal cassava yield (Fig. 5b). Similarly, the results carried out that cassava yield of summer crop can be obtained an optimal production if the sowing is shifted 2 weeks earlier compared to

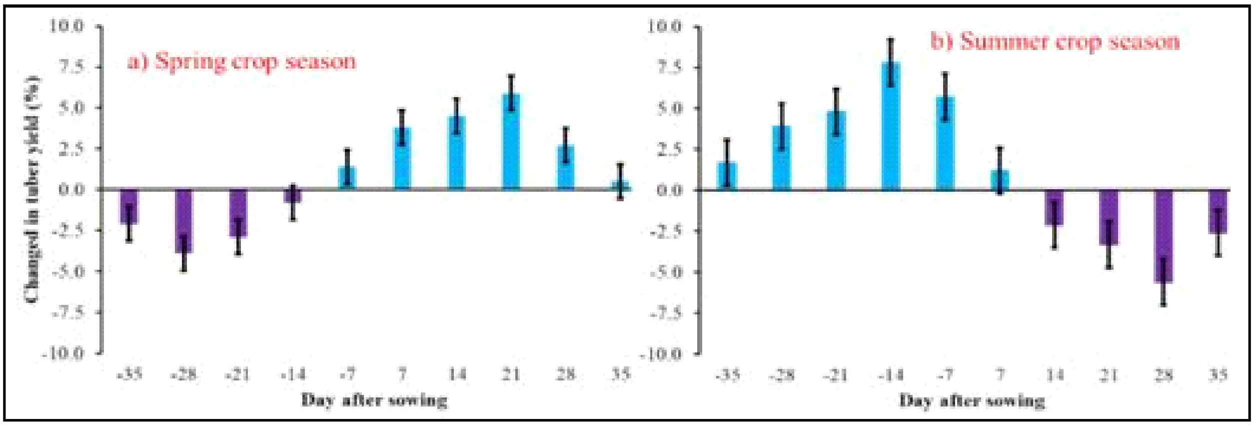

Fig. 4. Change in cassava yield under the sowing of the spring and summer crop.

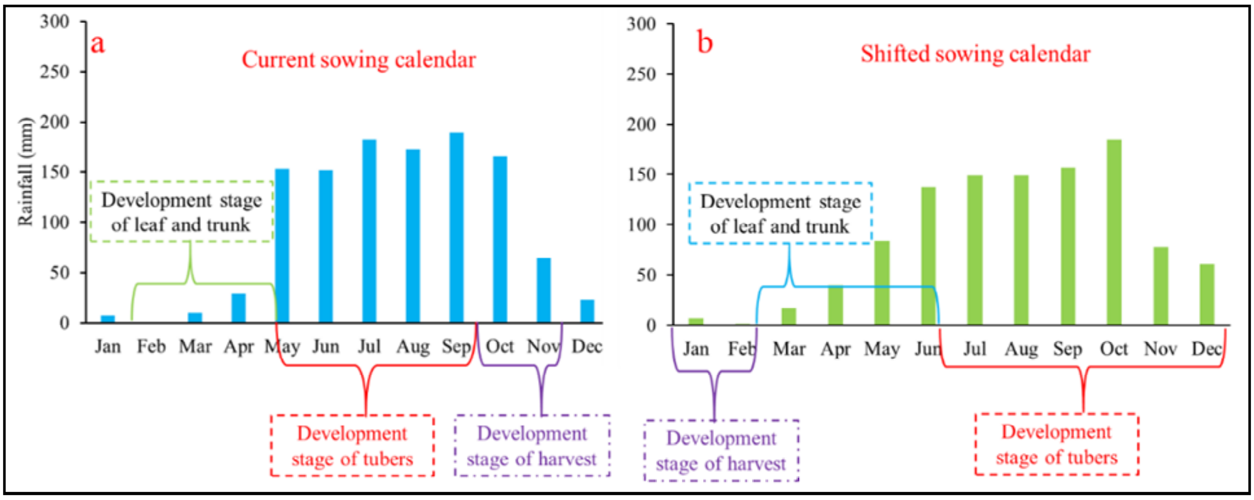

Fig. 5. Relationship between (a) Spring crop sowing with precipitation during 1985-2015 and (b) Altered sowing with precipitation during 2016-2019.

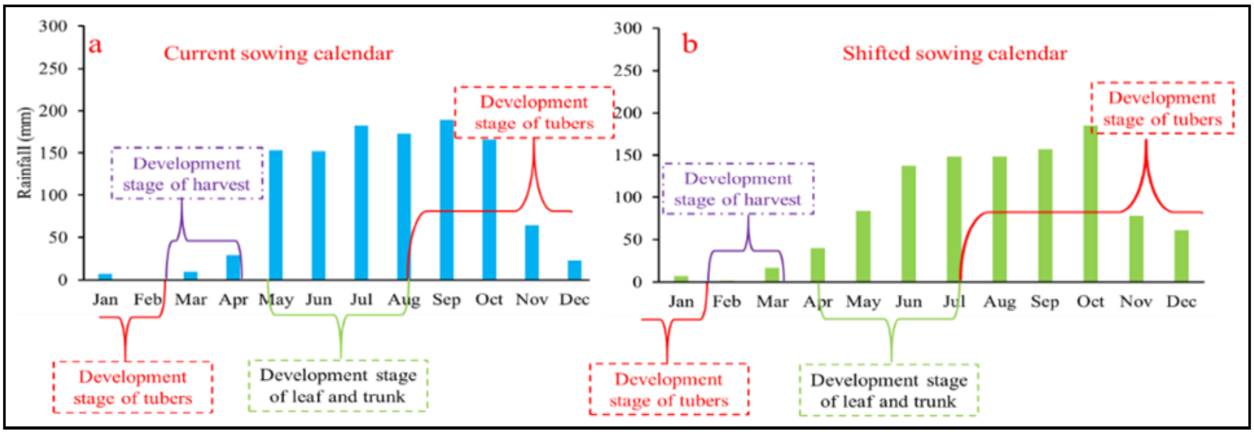

Fig. 6. Relationship between (a) Summer crop sowing with precipitation during 1985-2015 and (b) Altered sowing with precipitation during 2016-2019.

the current sowing (Fig. 6a). The analyzed results are in agreement with precipitation data because irrigation water from rain remained during the development stage of tubers (Fig. 6b).

In general, the cassava yield can be affected by sowing seasons. The above average yield of cassava to the tune of 2.6 and 3.1 t/ha may be obtained for a spring and summer crop, respectively if the sowings are done during the period of the OCE. However, the distribution of precipitation at the harvest stage of the spring and summer crops should be suitable to the harvest operations.

CONCLUSION

The applied CropWat model was significant in comparison of precipitation risks to cassava yield of the spring and summer crop across the study area through the high correlation of statistical errors (RMSE, R^2 and d). Based on the findings, the sowing should be altered for spring and summer crop of cassava to reach the optimal yields. In general, a change in the sowing of the spring and summer crops is suitable under the present rainfed features in the study area.

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