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Case Report

Calibration of the AquaCrop Model in Special Coffee (*Coffea arabica*) Crops in the Sierra Nevada of Santa Marta, Colombia

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Abstract

Background and Objective: This study proposed the application of the AquaCrop model in special coffee crops. Till now, no studies were found on the application of this model in this specific crop, which is the main contribution of this research study. In this way, the study aims to present the calibration of the variables related to type of crop, soil characteristics and management of special coffee agriculture in the Sierra Nevada of Santa Marta, Colombia. **Materials and Methods:** The theoretical bases considered for the present study focus on the different calibration methodologies of the AquaCrop model in different types of crops. The methodology used is based on the proposal of estimation, measurement, calculation and collection of the respective data of the model. Specifically, the project analyzed databases of climate, soil, crops and management practices. The researchers used the statistical techniques of ordinary least squares and the completion coefficient to perform the fit of the model. **Results:** The results of the calibration of AquaCrop for coffee (*Coffea arabica*) special have a coefficient of determination R^2 of 0.71 which indicates that the model is acceptable. In addition, it established a forecast of productivity with specific agroclimatic conditions. According to the calibrated model, the average temperature is the variable with the highest incidence in coffee productivity. **Conclusion:** The results presented in this paper contribute to the application of the AquaCrop model in coffee crops in different regions.

Key words: AquaCrop, calibration, special coffees, agroclimatic risk models, coffee agriculture

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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

The Food and Agriculture Organization of the United Nations (FAO) developed the AquaCrop model, in order to simulate the performance of crops in response to water policies. The reference model is the product of several researches worldwide and has successful adaptation and calibration experiences in places with different environmental conditions and characteristics of crops[1]. The AquaCrop model was established based on a complex biophysical process[2]. A review of the literature referring to the calibration of the AquaCrop model in different types of crops is presented.

The objective of the study is the use of the AquaCrop model to estimate yields for sugarcane cultivation in the department of Valle del Cauca[1], it was to adapt and validate AquaCrop for the cultivation of sugarcane in Colombian production areas, by evaluating the yield of that crop under different scenarios of variability and climate change. According to Bello *et al.*[1], the AquaCrop model proved to be a good tool to simulate the performance of sugarcane cultivation (*Saccharum officinarum*).

In the same way, in 2013 the study entitled "Use of the AquaCrop model to estimate yields for potato cultivation in the departments of Cundinamarca and Boyaca[3] was developed, in order to adapt and validate AquaCrop for the cultivation of potatoes (*Solanum tuberosum*) in the producing areas of Colombia and evaluate their performance under scenarios of variability and climate change. In the cited study, the effectiveness of the AquaCrop model was validated for the simulation and optimization of the potato crop, as well as for the design of strategies against the effects of climatic variability.

On the other hand, the adaptation and validation studies of the AquaCrop model carried out to estimate the yield of rice crops in the departments of Tolima and Meta[3] and the cultivation of corn in the Departments of Córdoba, Meta, Tolima and Valle del Cauca[1], under scenarios of variability and climate change, point out that the AquaCrop model and ETo Calculator are effective tools to design strategies to adapt to climate change or increase crop productivity. Additionally, the usefulness of the AquaCrop model was validated for the election of suitable sowing dates and to make adaptation decisions to environmental and anthropogenic phenomena (climatic variability) (prices, demand, supply).

Additionally, the calibration and validation of the AquaCrop model for Canola[4] was carried out through field experiments during the 2009 and 2010 growing seasons in the experimental canola sites of the Wagga Wagga Agricultural Research Institute. The calibrated model accurately simulated the evolution of canopy cover, biomass accumulation and grain yield, with low values of mean square error. However, the results showed that the model overestimated the biomass, the canola yield and, slightly, the water content of the soil.

In another work on the calibration and validation of the AquaCrop model for Bambara peanut with irrigation and water deficit[5], measures of canopy cover (CC), biomass (B) and pod yield (Y), taken from experiments were used. It selected greenhouse (2006 and 2007) and field (Botswana). Subsequently, the model was validated with independent sets of data from glass house (2002 and 2008) and field (Swaziland) for different land types. The AquaCrop simulations for CC, B and Y, of different native bambara peanut types are in agreement with the observed data; the coefficients of determination (R^2) were, CC: -0.88, B: -0.78 and Y: -0.72, respectively).

For its part, the study aimed to calibrate and validate the AquaCrop model applied to wheat, corn and soybeans as reference crops for the Río Cuarto region, in Argentina[6], carried out in 2012, used data from trials conducted in the experimental field of the UNRC. Calibration was done by modifying some model coefficients related to crops and management practices. The validation was verified with the methods of the coefficient of determination of the linear adjustment, the slope in 1:1 and the root of the mean square error (RECM). The resulting model presents an acceptable level of adjustment for the scale of work with errors of 5, 13 and 11% for corn, wheat and soybeans, respectively. The results indicated that AquaCrop presents sensitivity to certain hydrological parameters such as the amount of precipitation that occurred during the crop cycle, the amount of water transpired and the water content of the soil profile at planting, results that validate the applicability of the AquaCrop model[6].

On the other hand, the calibration and validation study for the simulation of potato (*Solanum tuberosum* L.) under different irrigation treatments with pivot in semi-arid conditions[7], published in 2013, was developed based on an experimental test carried out during the seasons of 2011 and 2012 in the Agro-environmental Training Center of Aguas Nuevas. According to the authors, the simulations performed with the model were good to excellent (NRMSE <20%) in relation to crop growth and harvest data observed in the field. In this way, the statistics standardized mean square error (NRMSE), coefficient of determination (R^2), average deviation (DM) and error frequency (EF), may be sufficient for future users of this type of models to have a level of enough approximation to evaluate their behavior[7]. This paper aims to expose the calibration of the AquaCrop agroclimatic risk model in special coffee crops of the Sierra Nevada of Santa Marta, Colombia, due to the lack of calibration studies of AquaCrop in this type of crops.

MATERIALS AND METHODS

The study conducted a literature review to determine the variables of each of the modules of the AquaCrop agroclimatic risk model, the project seeks to establish which variables are observed (measured), estimated, calculated or taken by default.

Location of the crop: The present project was carried out in coffee production units located in the municipality of Pueblo Bello, in the department of Cesar, Colombia located at 10°24'58" N and 73°34'58" W, has an altitude of 1093 m, its climate is tropical dry (Köppen climate classification: Aw). The productive units are the Equatorial, Sudandino andino and Páramo thermal peaks. The altitude of the municipal seat (in meters above sea level): 1200 m a.s.l. and has an average temperature between 289.15°K to 295.15°K (16°C to 22°C)[8].

The municipality of Pueblo Bello limits to the north, south and east with the municipality of Valledupar, Cesar and to the west with the municipality of El Copey, Cesar and the department of Magdalena. Figure 1 and 2 showed the location of the municipality of Pueblo Bello in the Northern zone of Colombia[8].

Climate characterization: For the development of the project, information was obtained from the Institute of Hydrology, Meteorology and Environmental Studies IDEAM[8] and its meteorological stations "Pueblo Bello" (10°25'4,4"N, 73°35'20"W and altitude of 1000 m) and "San Sebastián" (10°34'0"N, 73°36'0"W and altitude of 2000 m). Both located in the municipality of Pueblo Bello, Cesar. The observed variables were precipitation, maximum temperature, minimum temperature, relative humidity and reference evapo-transpiration, the measured data are for the period between 1981-2010.

In addition, the information was obtained from the Agro-climate meteorological network of the National Research Center of Coffee CENICAFE[10], with pertinent information on the climatic variables of rainfall, temperature and relative humidity, consolidated monthly and annually, registered by the Coffee Meteorological Network, in the time period between 1958-2016. Likewise, the concentration of CO_2 assigned by default in the AquaCrop model was used.

Characterization of the crop: Variables related to the cultivation module are determined: type of sowing, planting density (plants per m^2), size of foliage at planting, days to emergence, days at maximum canopy, canopy growth

Fig. 1: Macro location of the project

Source: Instituto Geográfico Agustín Codazzi[9], Available at: http://geoportal.igac.gov.co/ssigl2.0/visor/galeria.req?mapaId=7&title=Mapa%20Base [Accessed: November 28, 2017]

Fig. 2: Micro location of the project

Source: Instituto Geográfico Agustín Codazzi[9], Available at: http://geoportal.igac.gov.co/ssigl2.0/visor/galeria.req?mapaId=7&title=Mapa%20Base [Accessed: November 28, 2017]

coefficient, days at senescence, days of germination, cycle duration, flowering days, duration of flowering, days of grain formation, minimum depth of roots, maximum depth of roots, days at maximum root depth, tbase min (°K), tbase max (°K), stomatal closure, type of salinity. The data was obtained through open and in-depth interviews with agronomists from the National Federation of Coffee Growers of Colombia and the coffee growers of the study region.

Soil characterization: In the second instance, the variables related to the soil module of the AquaCrop model are determined: Horizons, description, thickness, permanent wilting point, saturation point. The data was obtained through the National Federation of Coffee Growers of Colombia and the coffee growers of the study region. The colombian Corporation of Agricultural Research CORPOICA, conducted a study of soil type with samples of the productive units, which included a physical analysis of non-taxed soils: different potential moisture (0.03 and 1.5 MPa+% saturation) and hydraulic conductivity. At the same time, another soil study was contracted with the AgustínCodazzi IGAC[10] Geographic Institute, where the real density, the field humidity and a physical-chemical characterization were analyzed, which included Cation exchange capacity, calcium content, magnesium, potassium, sodium, phosphorus, aluminum, base saturation, total carbon, texture and pH. For the results of the soil studies, analysis methods were used, such as; pH: Potentiometric (water dry soil 1:1); Organic matter: Walkley Black with K dichromate (M.O+0.6); phosphorus (P): Bray II (ppmP+4); Bases: Atomic absorption; Aluminum (Al): Yuan- Atomic absorption; touch texture and sum of bases: K+Ca+Mg (m/0.001 kg). For the interpretation of the results, it was taken as a sample to carry out the soil studies, the year 2017; in 10 productive units between zones: Low marginal, optimum zone and high marginal and soil management under shadows were taken into account.

Characterization of crop management: Regarding the variables related to the administration module of the crop, it was carried out through an open interview with agronomists and farmers of the productive units. These variables include, irrigation policies, use of organic fertilizers, management of pests by traditional methods, cleaning and weeding, among others. In addition, good practices of intervention of crops proposed by CENICAFE were taken into account and they are socialized in the productive units by the extensionists of the National Federation of Coffee Growers.

Statistical analysis: The researchers propose a multiple linear regression model for model calibration; specifically, by the technique of ordinary least squares and the coefficient of determination (R^2)[11]. Additionally, the project used the coefficient of determination R^2 because it corresponds to a method widely used in the literature regarding the calibration of the AquaCrop model:[1,5-7,12-18].

RESULTS AND DISCUSSION

According to the methodology proposed in this section, the results of the calibration of the AquaCrop model are presented. Table 1 presented the review of the literature, carried out in order to analyze the ways of measuring each of the variables of the AquaCrop modules. The table identifies the variables calibrated (measured or observed) with the letter "C" and the values taken by default with the letter "D". In this way, the researchers determine the use, observation or exploration of the values in each respective variable.

Product of the literature review associated with the calibration of the AquaCrop model, it is concluded that the following variables are estimated in the majority of cases by default: minimum effective rooting depth, maximum basal crop coefficient, upper threshold of salinity, lower threshold of salinity, bulk density, texture, soil depth, initial salinity (ECe), saturation moisture, field capacity moisture and hydraulic conductivity.

Additionally, the following variables were calibrated in most cases: base temperature, cut-off temperature, canopy cover per seedling at 90% emergence (CC0), canopy growth coefficient (CGC), crop coefficient for transpiration at CC = 100%, time from sowing to emergence, time from sowing to maximum canopy cover, time from sowing to harvesting, time from sowing to start senescence, time from sowing to maturity.

Table 1: Calculation of the variables according to the different authors

Variables of the AquaCrop model	Unit of measurement	Linker *et al.*[19]	Hassanli *et al.*[20]	Akumaga *et al.*[15]	Paredes *et al.*[21]	Kim y Kaluarachchi[12]	Iqbal *et al.*[22]	Flores-Gallardo *et al.*[23]	Xiangxiang *et al.*[24]	Abedinpour *et al.*[25]	Stricevic *et al.*[26]	Preference (calibrated or default)
Base temperature	°C	C	C	C	C	C	C	C	C	C	C	Calibrate
Cut-off temperature	°C	C	C	C	C	C	C	C	C	C	C	Calibrate
Canopy cover per seedling at 90% emergence (CC0)	cm^{-2}	C	C	C	C	C	C	C	C	C	C	Calibrate
Canopy growth coefficient (CGC)	%	C	C	C	C	C	C	C	C	C	C	Calibrate
Maximum canopy cover (CCx)	%	C	D	C	C	D	D	C	C	C	C	Both options
Crop coefficient for transpiration at CC = 100%	-	C	C	C	C	C	C	C	C	C	C	Calibrate
Maximum effective rooting depth	M	C	C	D	D	C	C	D	C	D	C	Both options
Minimum effective rooting depth	M	C	D	D	D	D	D	D	D	D	C	Default
Reference harvest index (HI0)	%	D	D	C	C	D	C	C	C	C	D	Both options
Water productivity	$g\ m^{-2}$	C	C	C	D	D	C	C	C	D	C	Both options
Maximum basal crop coefficient	-	C	C	D	D	D	D	D	D	D	D	Default
Upper threshold of salinity	$dS\ m^{-1}$	D	C	D	D	C	D	C	D	D	D	Default
Lower threshold of salinity	$dS\ m^{-1}$	D	C	C	D	C	D	C	D	D	D	Default
Time from sowing to emergence	Day	C	C	C	C	D	C	C	C	C	C	Calibrate
Time from sowing to maximum canopy cover	Day	C	C	C	C	C	C	C	C	C	C	Calibrate
Time from sowing to harvesting	Day	C	C	C	C	C	C	C	C	C	C	Calibrate
Time from sowing to start senescence	Day	C	C	C	C	C	C	C	C	C	C	Calibrate
Time from sowing to maturity	Day	C	C	C	C	C	C	C	C	C	C	Calibrate
Bulk density	$g\ cm^{-3}$	D	C	D	D	D	D	C	D	D	D	Default
Texture	-	D	C	D	D	D	D	C	D	D	D	Default
Soil depth	cm	C	C	D	D	D	C	C	D	D	D	Default
Initial salinity (ECe)	$dS\ m^{-1}$	D	C	D	D	D	D	D	D	D	D	Default
Saturation moisture	m^{-2}	D	C	D	D	D	D	D	D	D	D	Default
Field capacity moisture	m^{-2}	D	C	D	D	D	D	D	D	D	D	Default
Hydraulic conductivity	$mm\ h^{-1}$	D	C	D	D	D	C	D	D	D	D	Default

Conventions: C: Calibrated, D: By default

On the other hand, the following variables were taken by default and sometimes calibrated: Maximum canopy cover (CCx), maximum effective rooting depth, reference harvest index (HI0), water productivity.

Table 2: Calibration of the variables of the AquaCrop modules

Climate variables	
Precipitation (mm)	0.199661
Maxim temperature (°K)	300.15°K
Minimum temperature (°K)	1837.15°K
Relative humidity	80.86
Reference evapotranspiration	112.8
Crop variables	
Sowing type	Hint
Planting density (plants m^{-2})	0.6 plants/m^2
Size of foliage to sowing (cm^2/plant)	Up to 3m
Days to emergency	45 days
Days to maximum canopy	5 years
Coefficient of canopy growth	Up to 5 years
Canopy decay coefficient	Every year after 5 years it decays
Days to senescence	12 months
Germination Says	60 days
Duration cycle	3 years
Flowering days	2 years
Duration of flowering	3 a 5 days
Grain formation days	32 weeks
Minimum depth of roots (mts)	0.3 m
Maximum root depth (mts)	0.5 m
Days at maximum depth of roots	Up to 5 years
Tbase min (°K)	292.15°K
Tbase max (°K)	295.15°K
Soil variables	
Horizons	3
Thickness	0.1-0.6 m
Permanent withering spot	2-3 months
Saturation point	30 days a lot of water
Ph	5.5
Potassium	0.15
Calcium	4.1
Magnesium	1.2
Aluminum	0.2
Sodium	0.5
Match	6.3
Texture	Franc Arc-Sandy
Hydraulic conductivity	3
Suma bases	4.1
Management variables	
Net irrigation requirements	2000 mL water per year

Institute of Hydrology. Meteorology and Environmental Studies[8]; National Center for Coffee Research[10]

Calibration of the variables: Table 2 showed the results of the variables calibrated in the present study. The specification and procedures for obtaining the data presented in Table 2.

On the other hand, the works carried out in the productive units of the present project. conclude that the soil is suitable for the coffee crop according to the source material (Sandy Grain) and the hydraulic conductivity. Aluminum is determined when the pH is below 5.6 and should not exceed 1.1 me/100 g. According to the soil studies carried out. the samples have a good pH. respond little nitrogen application and require application of phosphorus (P). The sum bases. was within normal. For the level of potassium (K). calcium (Ca) and magnesium (Mg) are low, therefore, instead of agricultural lime. dolomite or dolomitic lime should be used.

Calibration of the AquaCrop model: The input data of the calibration for the climate module correspond to historical data from the last 10 years. reported by the National Center for Coffee Research[10]. According to Table 3, the investigation carried out the analysis by means of a multiple linear regression (ordinary least squares) from the historical data of the coffee production (dependent variable) and the climatic variables (independent variables).

The F-distribution appears frequently as the null distribution of a statistical test. especially in the analysis of variance. This established null hypothesis test statistic is obtained from the F-distribution if the null hypothesis is true. Therefore, the null hypothesis is rejected. with very little probability of error with 90% confidence level (0.10); concluding that the regression equation explains a significant percentage of the variance of coffee production presented in Table 4.

Table 3: Climatic input data for calibration

Year	Maximum temperature	Temperature average	Minimum temperature	Relative humidity	Rain	Production
2007	27.0	20.9	15.7	84.7	2298.6	18.7
2008	26.5	20.1	15.5	83.1	2355.9	18.9
2009	27.4	21.0	15.8	80.9	1695.7	19.5
2010	26.6	21.2	16.8	83.9	3036.2	21.2
2011	26.2	20.6	16.1	85.4	2524.4	22.7
2012	27.0	21.0	15.8	83.4	2280.8	25.31
2013	27.3	21.3	16.1	82.4	2090.6	27.50
2014	27.6	21.5	16.0	81.1	1836.7	27.24
2015	28.2	21.9	16.3	79.8	1140.7	26.13
2016	27.8	21.9	16.6	80.4	1791.1	26.31

Source: National Center for Coffee Research (CENICAFE)[10]

Table 4: Variance estimation

Parameters	Degrees of freedom	Sum of squares	Average of squares	F	Critical value of F
Regression	5	83.7491382	16.7498276	2.22330411	0.22945106
Waste	4	30.1350185	7.53375463		
Total	9	113.884157			

Table 5: Results of the student T-statistic

Parameters	Coefficients	Typical error	t-statistic	Probability	Lower 95%	Superior 95%	Bottom 90.0%	Superior 90.0%
Interception	512.77759	347.093139	1.47734868	0.21364303	-450.907457	1476.46264	-227.171803	1252.72698
Maximum temperature	-22.7351641	12.4956173	-1.81945105	0.14296824	-57.4285596	11.9582315	-49.3739057	3.90357755
Maximum temperature	25.915067	11.6314508	2.22801674	0.08980852	-6.37901753	58.2091515	1.11859607	50.7115379
Minimum temperature	-13.8821032	8.15950561	-1.70134122	0.16409683	-36.5365227	8.77231617	-31.2769191	3.51271257
Relative humidity	-2.31763267	1.70309138	-1.3608387	0.24519099	-7.0461724	2.41090707	-5.94836256	1.31309723
Rain	-0.00259847	0.00518514	-0.50113794	0.64259678	-0.01699473	0.01179779	-0.01365239	0.00845545

Hypothesis test of the coefficients of the individual parameters Eq. 1-10:

$$H_O = \beta_1 = 0 \quad (1)$$

$$H_O = \beta_1>0 \text{ó} \beta_1<0 \quad (2)$$

$$H_O = \beta_2 = 0 \quad (3)$$

$$H_O = \beta_2>0 \text{ó} \beta_2<0 \quad (4)$$

$$H_O = \beta_3 = 0 \quad (5)$$

$$H_O = \beta_3>0 \text{ó} \beta_3<0 \quad (6)$$

$$H_O = \beta_4 = 0 \quad (7)$$

$$H_O = \beta_4>0 \text{ó} \beta_4<0 \quad (8)$$

$$H_O = \beta_2 = 0 \quad (9)$$

$$H_O = \beta_5>0 \text{ó} \beta_5<0 \quad (10)$$

With the 90% level of confidence, the rejection region is performed (Student T) (Table 5):

$$T>t\infty \text{ó} T<\infty$$

The investigation accepts the average temperature variable with the Student T statistic (Eq. 11, 12), because, with 90% it is the only variable with a Student T statistic less than 10% which is considered generally considered very good[15].

$$H_O = \beta_3 = 0 \quad (11)$$

$$H_O = \beta_3>0 \text{ó} \beta_3<0 \quad (12)$$

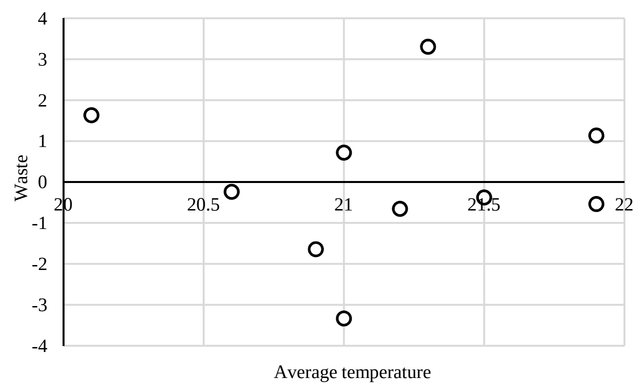

Fig. 3: Residuals of the average temperature

Determination of the equation and R^2, the model predicts the production of special coffee in high degree with the climatic conditions with the coefficient of determination (R^2) of 0.71 ($p<0.10$). That is the percentage of the average temperature can be explained by the production variable is 71%.

Subsequently, the graph of the residuals of the average temperature was presented (Fig. 3).

The residuals (error = y-y^) vs. the adjusted value (average temperature) showed in Fig. 3 that the residuals or errors do not present patterns so it was concluded that the variances were equal (homoscedasticity).

Prediction for a future value "Y"; According to the previous graph the differences of the observed data (26310 kg) and the simulated ones (27049000 kg), the difference was 1180 kg, which represents in average percentage terms for all the crops 4.48% (Fig. 4).

The following is a literature review of the different authors who used the multiple linear regression model as a statistical technique for data analysis of the AquaCrop model variables (Table 6). In the present study the result of the coefficient of determination R^2 was 0.71.

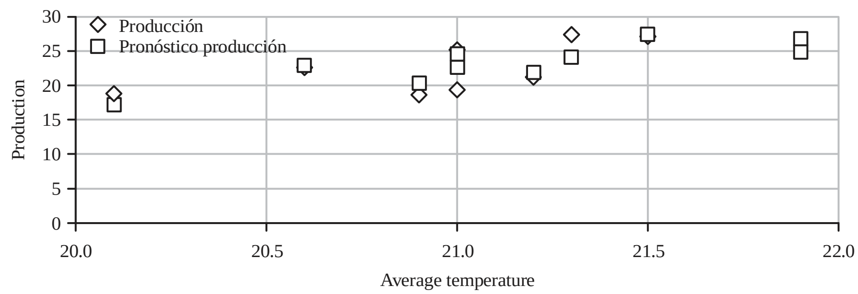

Fig. 4: Prediction for a future "Y" value

Table 6: Review of the literature using the linear regression model

References	Crops	Result of R^2 per variable
Morla y Giayetto[6]	Corn	Yield = 0.91
Morla y Giayetto[6]	Soy	Yield = 0.81
Morla y Giayetto[6]	Wheat	Yield = 0.77
Bello *et al.*[1]	Cane	Simulated and measured fresh stems for several growing cycles. Guacarí station = 0.92
		Simulated and measured fresh stems for several growing cycles. La Paila station = 0.91
Akumaga *et al.*[15]	Corn	Simulated grain production = 0.930
		Simulated biomass = 0.985
Bello y Walker[17]	Amaranth	Cobertura del dosel= 0.577
		Biomass = 0.92
		Cumulative evapotranspiration = 0.91
		Water content in the soil = 0.30
Ezekiel *et al.*[16]	Corn	Soil moisture = 0.87
		Simulated grain production = 0.84
		Simulated biomass = 0.82
		Water use of seasonal crops = 0.93
Hadebe *et al.*[18]	Sorghum	Simulated canopy coverage = 0.659
		Biomass = 0.79
		Harvest index = 0.967
		Yield = 0.923
Karunaratne *et al.*[5]	Peanut	Canopy cover = 0.88
		Biomass = 0.78
		Yield = 0.72
Perez-Ortola *et al.*[13]	Onion	Water content in the root zone in response to crop watering and transpiration = 0.93
Montoya [7]	Potato	Canopy coverage = 0.75
		Total dry matter = 0.95
		Moisture simulated = 0.55
Trombetta *et al.*[14]	Wheat	Green canopy cover = 0.957
Kim and Kaluarachchi[12]	Various	Estimated canopy coverage = 0.96
Mabhaudhi *et al.*[27]	Taro	Coverage of the canopy under irrigation conditions = 0.844
		Coverage of the canopy under temporary conditions = 0.018
		Canopy coverage adjustment = 0.799
		Biomass = 0.898
		Yield = 0.964
		Biomass independent data = 0.996
		Independent performance data = 0.980
		Coverage of the canopy under irrigation conditions = 0.844
		Coverage of the canopy under temporary conditions = 0.018
		Canopy coverage adjustment = 0.799
		Biomass = 0.898
		Yield = 0.964
		Biomass independent data = 0.996
		Independent performance data = 0.980
Lopez-Urrea *et al.*[28]	Barley	Performance = 0.98
		Biomass = 0.99
Zeleke *et al.*[4]	Canola	Dry biomass aboveground = 0.935

CONCLUSION

The AquaCrop model was calibrated by considering the data associated with the climatic variables to estimate the production of the coffee crops. Specifically it is concluded that the variable that directly influences production is the average temperature of the productive unit. From the historical data multiple linear regression was performed. obtaining a coefficient of determination (R^2) of 0.71 ($p = 0.10$). The indicated that the AquaCrop model variables allow to predict the production values of special coffee crops.

The results of the project allow to state that there is evidence in the literature about the calibration and validation of the AquaCrop agroclimatic risk model in different types of crops with acceptable levels of adjustment for the different modeled crops. The general determination coefficients oscillated in 0.72 and 0.98 with a high level of confidence.

For future research associated with the calibration of the AquaCrop model in coffee crops. It is suggested to perform the regression with all the variables of the model. As well as perform the field measurement of each of the variables to analyze the behavior of the adjustment coefficient of goodness of the model.

SIGNIFICANCE STATEMENT

There is no publications related to the agroclimatic risk models application in coffees or similar geographical regions to those developed in this study. This paper demonstrated the AquaCrop model application in special coffee crops, under specific climatic conditions. This work corresponds to an important contribution in the application of mathematical models to the cultivation techniques. In such a way, this may help to consult about an alternative to improve the productivity of coffee crops through the agroclimatic risk models application.

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