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Cassava yield prognostic (Manihot esculenta Crantz) using modeling in Calixto García, Holguín

Predicción del rendimiento de la yuca (*Manihot esculenta* Crantz) mediante la modelación en Calixto García, Holguín

Predição do rendimento da mandioca (Manihot esculenta Crantz) através de modelagem em Calixto García, Holguín

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ABSTRACT

Cassava is a cultivation of marked importance at global level and it constitutes the nutritious base of more than 500 million people. In Cuba, it is cultivated in all the provinces of the country with significant production volumes, however, technologies that favor the presence of processes of degradation of the soils and limit their productive potentialities persist. The yields reached in Calixto García Municipality oscillate around 15 $t.ha^{-1}$, very below the national average. This investigation was developed with the objective of calibrating the CSM-MANIHOT-Cassava and validating the genetic coefficients in function of the yields for the clone "Señorita" under the conditions of Holguín Province. The experiments were carried out in two properties of the Credits and Service Cooperative "Julio Sanguily" in different plantation dates and using three space arrangements. For the validation, yields reached by producers in the study area in different campaigns were used and the values of the RMSEn were determined. The results of the validation showed values of standardized error mean square of 9.8% and 11.2% for the 2 campaigns used, it demonstrates the appropriate adjustment of the model and the feasibility of its utilization for cassava.

Key words: simulation; prognostic; DSSAT; genetic coefficients; agricultural management; cassava.

RESUMEN

La yuca es un cultivo de marcada importancia a nivel global y constituye la base alimenticia de más de 500 millones de personas. En Cuba se cultiva en todas las provincias del país, sin embargo, persisten tecnologías que favorecen la presencia de procesos de degradación del suelo y limita sus potencialidades productivas. Los rendimientos en el municipio de Calixto García oscilan alrededor de las 15 t ha^{-1}, muy por debajo de la media nacional. El objetivo de la investigación fue proponer alternativas de manejo para el cultivar de yuca Señorita, basadas en los arreglos espaciales y las condiciones edafoclimáticas del municipio de Calixto García, utilizando la modelación. Se realizaron experimentos en dos fincas de la Cooperativa de Créditos y Servicios "Julio Sanguily" con el empleo de tres arreglos espaciales. Los resultados de la validación mostraron valores de la raíz del cuadrado medio del error normalizado de 9.8 % y 11.2 % para las dos campañas empleadas. Las simulaciones evidenciaron que los arreglos espaciales más adecuados son 0.90 m x 0.90 m y 1.20 m x 0.70 m que es donde se alcanzan los mayores rendimientos y las mayores utilidades con valores de 227867.23 CUP ha^{-1} para el suelo Fersialítico Pardo Rojizo.

Palabras clave: simulación; pronóstico; DSSAT; coeficientes genéticos; manejo agrícola; Yuca.

RESUMO

A mandioca é uma cultura de marcada importância a nível global e constitui a base nutricional de mais de 500 milhões de pessoas. Em Cuba é cultivado em todas as províncias do país, porém persistem tecnologias que favorecem a presença de processos de degradação do solo e limitam o seu potencial produtivo. A produtividade no município de Calixto García oscila em torno de 15 t ha-1, bem abaixo da média nacional. O objetivo da pesquisa foi propor alternativas de manejo da cultivar de mandioca Señorita, com base nos arranjos espaciais e nas condições edafoclimáticas do município de Calixto García, por meio de modelagem. Foram realizados experimentos em duas fazendas da Cooperativa de Crédito e Serviços "Julio Sanguily" utilizando três arranjos espaciais. Os resultados da validação apresentaram valores da raiz quadrada média do erro normalizado de 9,8% e 11,2% para as duas campanhas utilizadas. As simulações mostraram que os arranjos espaciais mais adequados são 0,90 m x 0,90 m e 1,20 m x 0,70 m, que é onde são alcançados os maiores rendimentos e os maiores lucros com valores de 227.867,23 CUP ha-1 para o solo Fersialítico Marrom Avermelhado.

Palavras-chave: Simulação; Previsão; DSSAT; Coeficientes genéticos; Gestão agrícola; Mandioca.

INTRODUCTION

Cassava is one of the most widely used traditional crops in tropical America and Africa. It is the food staple of more than 500 million people in tropical regions of the world (João, 2017; Markos et al., 2016) and ranks second in production among roots and tubers (FAO, 2020).

It is predicted that by 2050 its consumption will increase by 8% compared to 2010 (Scott, 2021; Rankine et al., 2021). FAO statistics predict that the volume of global cassava trade will remain stable over the next few years (FAO, 2020; FAO, 2019).

Africa is the world's largest producer with an annual production of 169 million tons in 2018 (Lehmane et al., 2022). The following countries stand out on this continent: Nigeria, the Democratic Republic of Congo, Ghana, Angola and Mozambique with a production close to 130 million tons; next is the Asian continent, represented by Thailand, Indonesia, Cambodia and Vietnam with a production of 70.7 million tons and in America, Brazil is the largest producer with 18.8 million tons (FAO, 2020).

Cassava is also grown in Latin America and the Caribbean, although its production only reaches 18.6% of the world's production due to the occurrence of extreme weather events and the increase in the effects of climate change (FAO, 2020; FAO, 2019).

In Cuba, it is cultivated in all the provinces of the country, however, the yields obtained are variable in correspondence with the characteristics of the soils, the behavior of the meteorological variables, the selected cultivars and the management system used in the different regions of the country (Mojena & Bertolí, 2004).

In the municipality of Calixto García, the yields obtained with cassava are close to 15 t ha^{-1} in 2020, this yield is below the 30.5 t ha^{-1} established as the potential yield of the crop at the national level (ONEI, 2021).

Given this situation, the importance of seeking alternatives for agricultural use according to the edaphoclimatic conditions of agroecosystems is ratified, aimed at achieving substantial increases in yields in degraded soils and under specific management conditions and changing climate change scenarios (FAO, 2022; IPCC, 2021).

Crop simulation models are essential tools to provide reliable information for decision-making (Moreno et al., 2021, 2020; Rodríguez et al., 2020; Rodríguez, 2019). These models allow the evaluation of available resources, assess a large number of plant-environment-management interactions and facilitate decision-making, quantifying production risk based on a probability analysis taking historical series of daily climate data and soil characteristics (Noriega et al., 2021).

The comprehensive analysis of these factors allows the design of appropriate management strategies (Ume et al., 2022; Rankine et al., 2021; Otaiku et al., 2019; Rodríguez, 2019).

Crop models allow simulating, analyzing and interpreting different future scenarios due to modifications that may be proposed in crop management, changes in climatic conditions or for yield forecasting, among other indicators (Rodríguez, 2023; Ume et al., 2022; Rodríguez et al., 2020).

DSSAT (Decision Support System for Agrotechnology Transfer) is a popular crop model used in more than 100 countries for more than 20 years and used in several crops including cassava (Jones, 2023; Hoogenboom et al., 2021).

Therefore, the goal of this research is to design agricultural management alternatives for the cassava cultivar “Señorita” based on the spatial arrangements and soil and climate conditions of the municipality of Calixto García, using the DSSAT crop simulation model.

MATERIALS AND METHODS

Study site description

The research was carried out in the municipality of Calixto García, in the province of Holguín, geographically located according to the Cuba Sur coordinate system at 20°53’58” N latitude and 76°26’51” W longitude and with an altitude of 104 m above sea level (Figure 1).

In general, the territory is dominated by Sialitic Brown soils with the presence of carbonates (Hernández et al., 2015), Haplic Eutric Cambisol (WRB World Reference Base for Soil Resources, 2014). The average annual temperature is 25.6 °C and rainfall ranges between 800 mm and 1200 mm per year with long periods of drought (ONEI, 2021).

Soil type and key characteristics

The soil profile characteristics were obtained from samples taken at two depths (0-10 cm and 10-20 cm). The soil pH (H_2O) was determined by the potentiometric method. The organic matter content was determined by the Walkley and Black method and the organic carbon content was calculated using the relationship: Organic matter = 1.724 × Organic carbon (Phoncharoen et al., 2021). The total nitrogen content was determined by the relationship: % Nitrogen = % Organic matter x 0.05.

Calcium and magnesium content (Cmol kg^{-1}) were determined by the volumetric method with EDTA, the electrical conductivity (µs cm^{-1}) by the potentiometric method and the total soluble salts (mg L^{-1}) by the saturated paste method. In general, the analyses were carried out according to the methodology proposed by Paneque et al. (2010). The results of the analyses performed are shown in (Table 1).

The values of the physical and hydrophysical properties of the soil for the operation of the model were assumed from those disclosed by Cid et al. (2012) when determining the physical characteristics that define the hydraulic behavior of some soils in Cuba.

Table 1. Soil analysis results. **Source:** own elaboration.

Farm	Depth (cm)	Ca Cmol (+)kg^{-1}	Mg Cmol (+)kg^{-1}	MO (%)	pH	SST (mg L^{-1})	CE (μs cm^{-1})
Farm 1	0-10	34.5	11.5	1.31	7.8	58.4	119.1
	11-20	36.0	11.5	1.45	7.6	90.5	192.0
Farm 2	0-10	35.0	10.0	2.30	8.3	127.7	270.0
	11-20	35.0	10.0	1.75	8.2	133.8	278.0

Soil preparation, treatments and experimental design

Soil preparation was carried out using animal traction and the selected planting method was horizontal at the bottom of the furrow, which is the traditional method used by farmers in the study area.

The experimental design used was randomized blocks with three treatments and four replications. The size of the experimental plots was 25 m^2. Three different spatial arrangements were used to calibrate the model: 0.90 m x 0.90 m, 1.20 m x 0.70 m and 2.0 m x 0.60 m (Table 2).

Table 2. Spatial arrangements used in calibration. **Source:** own elaboration.

Spatial arrangements	Number of plants ha^{-1}
0.90 m x 0.90 m	12345
1.20 m x 0.70 m	11904
2.0 m x 0.60 m	8333

Zayas et al. (2023) describes calibration and validation of the CSM-MANIHOT-casava model. For simulation, in addition to the spatial arrangements of 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m were included as established by INIVIT, (2007).

Model evaluation

For the evaluation of the CSM-MANIHOT-cassava model, data on soil profile characteristics, daily meteorological variable behavior, detailed elements of the crop management system, and cultivar genetic coefficients are required (Rankine et al., 2021; Hoogenboom et al., 2019). The data were entered into the model in the form of input files and in DSSAT format. The cultivar genetic coefficients were obtained from Zayas et al. (2023).

For the application of the CSM-MANIHOT-cassava model, daily data on meteorological variables (maximum temperatures, minimum temperatures, and precipitation) were obtained from the meteorological station “La Jíquima” in the municipality of Calixto García. Solar radiation was determined by the calculation method according to the methodology proposed by Allen et al. (1998).

Data statistical analysis

Data processing was performed, the means and coefficient of variation of the variables studied in each experiment were calculated, a simple analysis of variance was applied and significant differences between the variables in both sowing dates were verified by Tukey's multiple range test $p < 0.05$. The RMSEn statistic was determined to evaluate the model fit, for the statistical analysis of the data the SPSS software for Windows, version 21.0, was used.

Economic analysis

The costs of each of the activities carried out for the establishment of the crop, such as the acquisition of seed, labor expenses for cultural care, harvesting, and the selling price of cassava in the market, were determined. A cost sheet was prepared for each of the spatial arrangements and soil types considered in the simulation. These elements were used to assess the cost-benefit ratio for each of the proposed alternatives according to the methodology proposed by (Ortiz et al., 2014). The seed prices, labor costs for the development of cultural care, harvesting, and the selling price of cassava were obtained from the economic area of the Julio Sanguily Credit and Services Cooperative (CCS), corresponding to those marketed by this productive form.

RESULTS AND DISCUSSION

Model evaluation

The results obtained in crop yield and harvest index in the two farms between the observed and simulated values, as well as the goodness of fit indicators of the model (**RMSE** and **RMSEn**) are shown in Table 3.

In general, for the three spatial arrangements in the two sowing dates, the crop yields and the predicted harvest index values showed a good correspondence in relation to those observed with **RMSE** = 1687.30 kg ha^{-1} and **RMSE** = 0.107 kg ha^{-1}, respectively.

For these evaluated parameters, the **RMSEn** behaved with values between 10 % and 20 %, which demonstrates a good fit of the model.

Table 3. Behavior of the main variables in calibration. **Source:** own elaboration.

Farm	Spatial arrangements	Yield (kg ha^{-1})		Harvest index	
		Oi	*Si*	*Oi*	*Si*
Farm 1	0.90 m x 0.90 m	16 149	16 455	0,90	0,99
	1.20 m x 0.70 m	14 806	16 455	0,88	0,99
	2.0 m x 0.60 m	13 862	11 604	0,90	0,99
Farm 2	0.90 m x 0.90 m	16 561	17 377	0,90	0,99
	1.20 m x 0.70 m	14 766	17 377	0,88	0,99
	2.0 m x 0.60 m	12 564	13 863	0,90	0,99
RMSE		1687,30		0,107	
RMSEn		11,2%		10,7%	

Behavior of simulated yields for cassava based on spatial arrangements and soil type.

Crop yields for each of the spatial arrangements evaluated on the brown carbonate soil are shown in Figure 1.

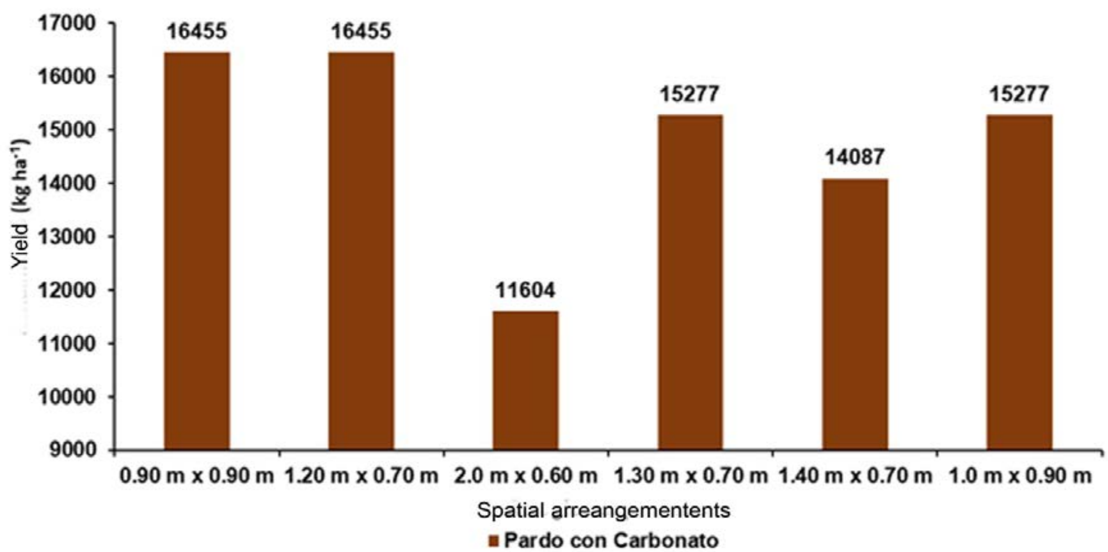

Figure 1. Behavior of yields depending on the spatial arrangements for the Brown soil with Carbonate.

Regarding the behavior of the yields in each of the spatial arrangements for the Brown soil with Carbonate, it can be seen that the highest yields are estimated in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.90 m, both with 16,455 kg ha-1, surpassing the arrangements of 2.0 m x 0.60 m, 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m by 4,851 kg, 1,178 kg, 2,368 kg and 1,178 kg, respectively.

The lowest yield for this type of soil is predicted in the spatial arrangement of 2.0 m x 0.90 m with 11,604 kg ha^{-1}. In this sense, previous studies carried out on the management and the effect of mycorrhizal biofertilizers in the municipality of Santo Domingo, province of Villa Clara, on a Brown soil with Carbonate, for the Señorita cultivar and using the spatial arrangement of 0.90 m x 0.90 m, Ruíz et al. (2010) report yields in the order of 24,670 kg ha^{-1} with 25% mineral fertilization of complete NPK formula.

In this regard, Rivera et al. (2012) when evaluating the effectiveness of the EcoMic® biofertilizer in the cultivation of the Señorita cassava cultivar in this type of soil and using the spatial arrangement of 0.90 m x 0.90 m reported a yield of 15,450 kg ha^{-1}, similar to those obtained in this study. In later studies carried out at INIVIT, Villa Clara province, when carrying out the morphological and agronomic characterization of 50 Cuban cassava cultivars using the spatial arrangement 0.90 m x 1.0 m and on a Sialitic Brown soil with Carbonates, yields for the Señorita cultivar were reported with values of 19,010 kg ha-1 (Beovides et al., 2014), higher than those obtained in this work.

In this sense, more recent research developed in areas of INIVIT, in the central region of Cuba and aimed at evaluating the effectiveness of AMF strains in cassava cultivation in two types of soil, João et al. (2016) report yields higher than 25,900 kg ha^{-1} for the Señorita cultivar using the spatial arrangement of 0.90 m x 1.0 m.

In the analysis of the predicted yields for the spatial arrangements evaluated on a Brown soil without Carbonate (Figure 2) it is observed that the highest values of this variable are estimated in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, both with a yield of 13547 kg ha^{-1}, surpassing the spatial arrangements of 2.0 m x 0.60 m, 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m by 3803 kg, 961 kg, 1933 kg and 961 kg, respectively.

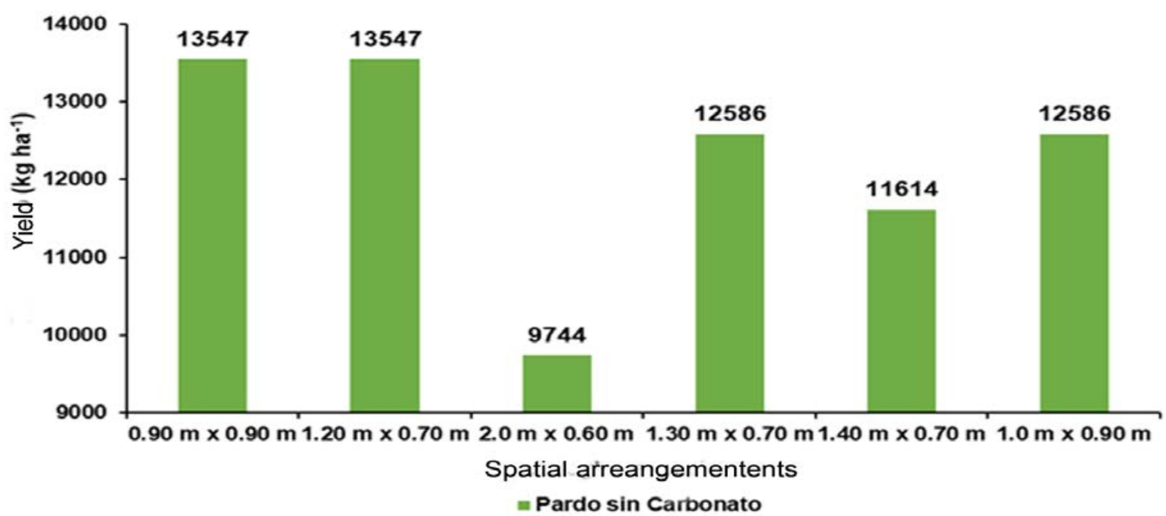

Figure 2. Behavior of yields in the spatial arrangements evaluated on a Brown soil without Carbonate.

The lowest estimated yield for this type of soil is obtained in the spatial arrangement of 2.0 m x 0.60 m with 9744 kg ha^{-1}. In this regard, previously developed research in the municipality of Calixto García on this crop with the local ecotype "Selección Holguín" with the spatial arrangement of 0.90 m x 0.70 m and on a Sialitic Brown soil without Carbonate report yields of 7500 kg ha^{-1} (Zayas et al., 2019), which differ from those obtained in this work, these results may be attributable to the fact that a different cultivar than the one used in this research was used.

On the other hand, in research carried out in Mexico on a comparative study of the yields of this crop in two spatial arrangements (1.20 m x 0.50 m and 1.20 m x 0.80 m) on Brown soils without Carbonates in Cárdenas municipality, Magaña et al. (2020) report yields of 13,200 kg ha-1 for the spatial arrangement of 1.20 m x 0.80 m, similar to those obtained in this research.

In this sense, in subsequent studies carried out in Jamaica when evaluating the CSM-MANIHOT-Cassava model to determine the benefits of the irrigation potential of four cassava cultivars, Rankine et al. (2021) report yields of 13,411 kg ha-1 for the spatial arrangement of 1.50 m x 0.60 m in the town of Bernard Lodge, similar to those obtained in this research.

The behavior of the predicted yields for each spatial arrangement evaluated on a Reddish Brown Fersialitic soil is shown in (Figure 3).

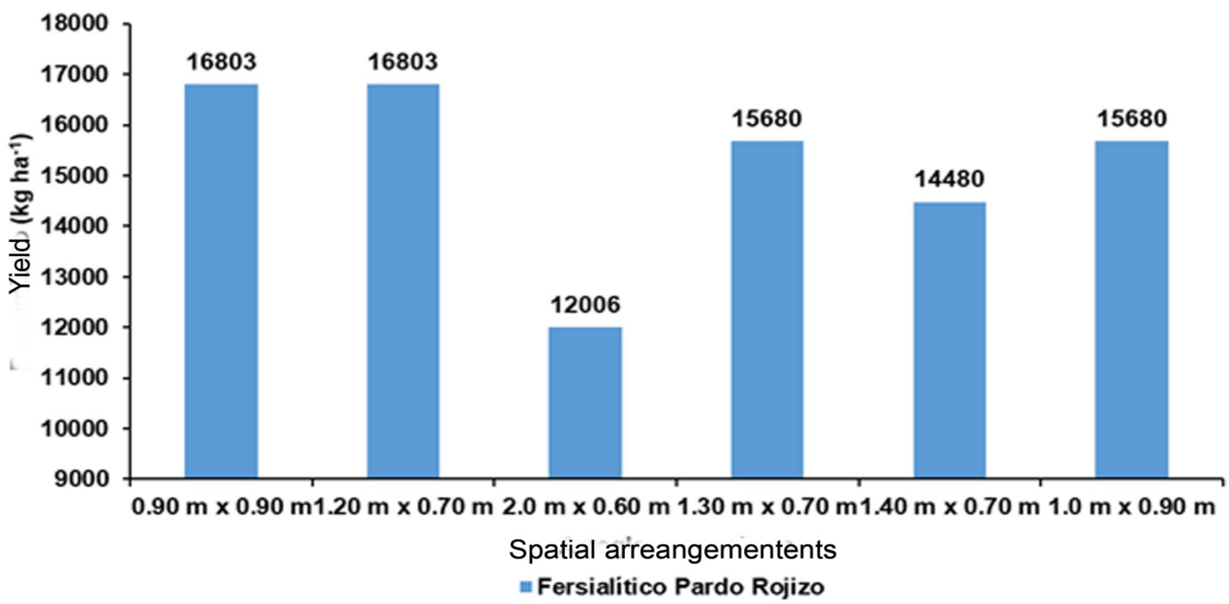

Figure 3. Behavior of yields in the spatial arrangements evaluated on a Reddish Brown Fersialitic soil.

As can be seen, the highest estimated yield values are obtained in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, both with 16,803 kg ha^{-1}, which exceed the spatial arrangements of 2.0 m x 0.60 m, 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m by 4,797 kg, 1,123 kg, 2,323 kg and 1,123 kg, respectively. The lowest predicted yield value is obtained for the spatial arrangement of 2.0 m x 0.90 m with 12,006 kg ha^{-1}.

Higher results are reported by Photangthan et al. (2022) when studying the ability of the CSM-MANIHOT-Cassava model to determine biomass production in erect and branched cultivars in Thailand, in different spatial arrangements, where they obtained simulated yields of 18486 kg ha^{-1} in the Rayong 9 cultivar in the spatial arrangement of 1.20 m x 0.80 m.

The yield behavior for each spatial arrangement evaluated on a Dark Plastic soil is shown in (Figure 4).

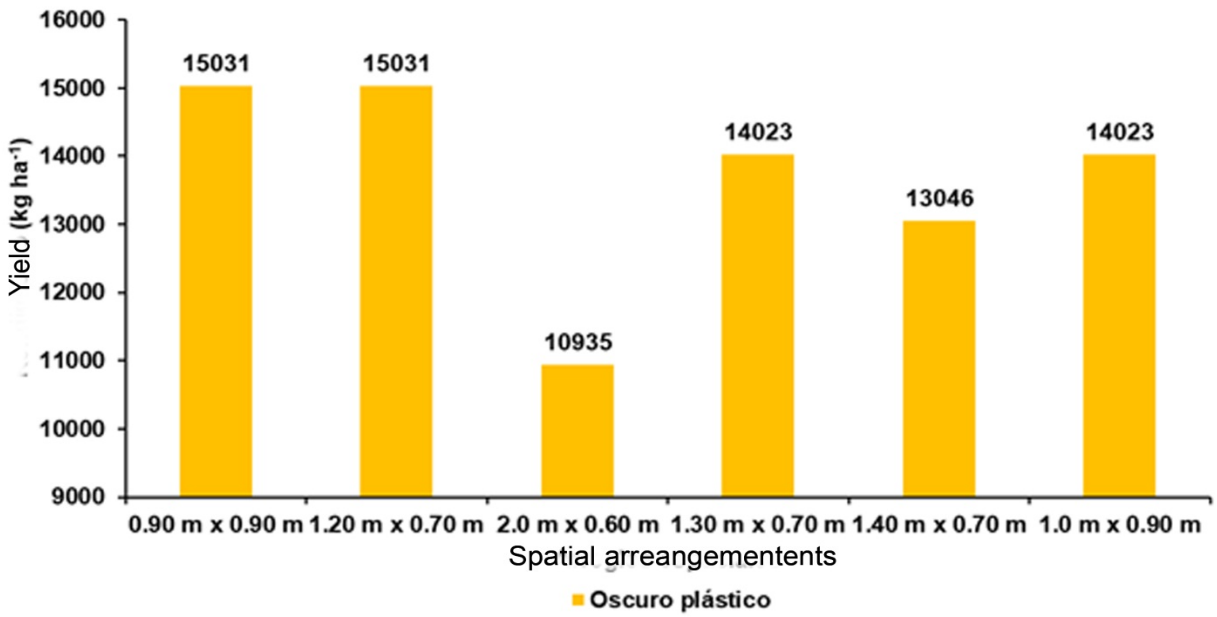

Figure 4. Behavior of yields in spatial arrangements evaluated on a Dark Plastic soil.

As can be seen, the highest estimated yield values were obtained in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, both with 15031 kg ha^{-1}, which exceed the arrangements of 2.0 m x 0.60 m, 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m by 4096 kg, 1008 kg, 1985 kg and 1008 kg, respectively.

The behavior of the yields for each spatial arrangement in Dark Plastic Non-Gleysy soils are shown in (Figure 5).

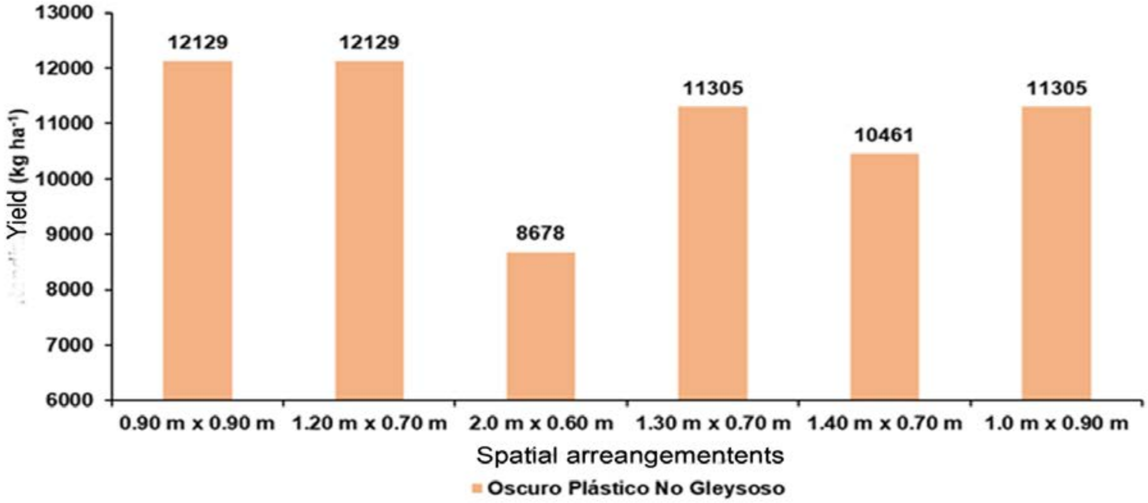

Figure 5. Behavior of yields in the spatial arrangements evaluated on a Dark Non-Gleyso Plastic soil.

When performing the analysis, it is observed that the highest estimated yields are achieved in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m with 12,129 kg ha^{-1}, the lowest yield value is obtained for the arrangement of 2.0 m x 0.90 m with 8,678 kg ha^{-1}.

Analysis of the performance of cassava crop yields under different management alternatives

When observing the results obtained, it can be seen that the highest yield values are obtained in the spatial arrangements 0.90 m x 0.90 m and 1.20 m x 0.70 m, both with a yield of 12,129 kg ha^{-1}, which exceed the spatial arrangements of 2.0 m x 0.60 m, 1.30 m x 0.70 m, 1.40 m x 0.70 m and 1.0 m x 0.90 m by 3,451 kg, 824 kg, 1,668 kg and 824 kg, respectively. The lowest yield value is obtained for the spatial arrangement of 2.0 m x 0.90 m with 8,678 kg ha^{-1}.

In general, when analyzing the behavior of the predicted yields based on the spatial arrangements and the soil type (Figure 6), it is seen that the highest yields are achieved in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m for all soil types. It is also evident that the highest yields are obtained for the Reddish Brown Fersialitic soil type in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, both with a yield of 16803 kg ha^{-1}, surpassing the Brown with Carbonate, Brown without Carbonate, Dark Plastic and Dark Plastic Non-Gleysy soils by 348 kg, 3256 kg, 1772 kg and 4674 kg, respectively.

The lowest yield values are obtained in the spatial arrangement of 2.0 m x 0.60 m for the six types of soils evaluated.

The analysis also shows that although the lowest yield values were predicted in the spatial arrangement of 2.0 m x 0.60 m, they varied depending on the type of soil, with the lowest value being obtained in the Dark Plastic Non-Gleysy soil with 8678 kg ha^{-1}.

It is evident that the estimated yields that predominate in the municipality with 32.96 % of the total evaluated area are 16,803 kg ha^{-1}, corresponding to the highest obtained from the simulation for the spatial arrangements 0.90 m x 0.90 m and 1.20 m x 0.70 m. This corresponds to the soils of the Reddish Brown Fersialitic type. This behavior is related to the suitability of these soils for the cultivation of cassava given the adequate pH range with values that oscillate between 7.5 and 7.6 and a texture with values of 23.5 % silt, 41.2 % sand and 35.3 % clay on average. Properties that favor the development of tuberous roots and contribute to maintaining adequate soil moisture for crop development, a factor of utmost importance for increasing yields (FAO, 2018).

These results allow for the adoption of productive strategies to concentrate the largest planted areas of the crop in agricultural settings with these edaphoclimatic conditions.

Next in order of importance are the yields of 16,445 kg ha^{-1} and 15,031 kg ha^{-1}, with an area representing 22.86 % and 13 % of the total area studied, respectively. These yields correspond to the presence of Brown soils with carbonate and Dark Plastic soils, in the order in which they are mentioned above. This behavior corresponds to their properties.

For Brown soils, despite having an optimal pH for crop development with values between 7.6 and 7.8, the organic matter content in the first 20 cm of depth ranges between 1.31 % and 1.45 % classified as very low, which influences the low chemical fertility of the soil. In addition, these soils have a texture with values ranging around 51 % sand, 27 % clay and 21 % silt for the Brown soils with Carbonate and between 12 % sand, 65 % clay and 23 % silt for the Dark Plastic soils. In both cases there is the presence of clay from the smectic group, all of which can limit the retention of soil moisture and thus limit the proper development of the roots.

Finally, the lowest simulated yields in the municipality for the different spatial arrangements correspond to 13,547 kg ha^{-1} and 12,139 kg ha^{-1}, for 23.27 % for the Brown Type soils without Carbonate and 7.91% for the Dark Plastic Non-Gleyized.

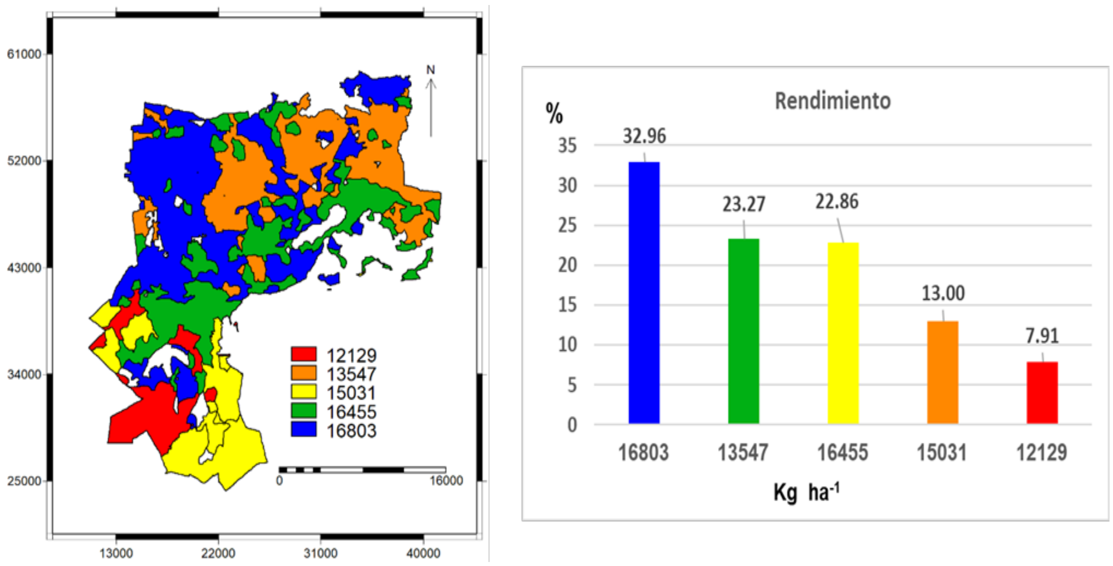

Figure 6. Spatial representation of the optimal yields for the spatial arrangements of 0.9 m x 0.9 m and 1.20 m x 0.70 m by soil type in the municipality of Calixto García.

Brown soils without Carbonate are characterized by alkaline pH values, with ranges between 8.2 - 8.3 in the first 20 cm of depth, low organic matter content (1.25 %) and low Nitrogen content (0.15 %), elements that denote low fertility, which influences the proper development of the crop, while in the Dark Plastic Non-Gleysy soils they may present poor drainage, which affects the air-water ratio necessary for the proper development of the crop roots.

The above leads to the fact that the most suitable management alternatives for the Dark Plastic Non-Gleysy soil are based on the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, this soil being the least appropriate of those used in the research for the establishment of the crop in the territory. Aspects to consider when establishing sustainable productive strategies for the agricultural production of cassava.

Economic analysis

When carrying out the economic assessment of the estimated results for each type of soil based on the spatial arrangements, it is evident that the highest utilities are generally predicted in the spatial arrangements 0.90 m x 0.90 m and 1.20 m x 0.70 m. The highest utilities for the studied territory are estimated in the spatial arrangements 0.90 m x 0.90 m and 1.20 m x 0.70 m for the Reddish Brown Fersialitic soil with 227867.23 CUP.

While the lowest utilities are predicted for the spatial arrangement of 2.0 m x 0.60 m in all types of soils evaluated, the lowest estimates being for the Brown soils without Carbonate and Dark Plastic non-gleys with 127,685.83 CUP and 112,502.53 CUP, respectively.

From an economic point of view, it is estimated that the most recommended soil for the cultivation of cassava in the territory is the Reddish Brown Fersialitic soil with the use of spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m, which facilitates decision-making and applying adequate productive strategies to establish the largest plantations of the crop in this soil type.

CONCLUSIONS

During the model evaluation, it was established that the prediction was statistically between excellent and good, with RMSEn values of 9.8 % and 11.2 % for the variables studied, which demonstrates the good fit of the model and the feasibility of its use to simulate the behavior of cassava in the conditions of Cuba and specifically, of the municipality of Calixto García, Holguín.

The simulation allowed to estimate that the highest yields for the territory are based on the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m for each soil type, being in the Reddish Brown Fersialitic soil where the highest values are predicted with 16803 kg ha^{-1}.

The economic analysis carried out with the DSSAT model confirms that the highest profits are predicted in the spatial arrangements of 0.90 m x 0.90 m and 1.20 m x 0.70 m for the Reddish Brown Fersialitic soil with 227867.23 CUP, which determines the feasibility of its practical application.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this article.