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Manejo de escenarios mediante clima y suelo en la producción de caña de azúcar (Saccharum officinarum) 2010-2020: Valle del Grullo-Autlán, Costa Sur de Jalisco

Management of climate and soil scenarios in the production of sugarcane (Saccharum officinarum) 2010-2020: Valle del Grullo-Autlán, Southern Coast of Jalisco

Cenários de gerenciamento usando clima e solo na produção de cana de açúcar (Saccharum officinarum) 2010-2020 Valle del Grullo-Autlan, Jalisco South Coast

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Resumen

Los modelos como herramientas de simulación constituyen un medio para entender la complejidad de un determinado sistema; los modelos se consideran elementos disponibles y necesarios para entender las hipótesis en sus procesos. Un modelo permite generar situaciones reales y complejas con base en sistemas de simulación que admiten tomar decisiones de cualquier índole. Este trabajo presenta, con apoyo del software VENSIM, escenarios propicios para la producción de caña de azúcar en el Valle El Grullo-Autlán, así como la validación del mismo con apoyo del software SPSS (versión 15.0). Los resultados muestran la manera como los factores suelo y precipitación repercutirán directamente y a futuro en la producción de caña por hectárea en el Valle El Grullo-Autlán. En este caso, el modelo cuadrático y el cúbico fueron estadísticamente significativos para el caso de la precipitación, no así la temperatura, lo que se suma al historial de temperaturas de los últimos 14 años en la región, el cual no presenta injerencia alguna hasta el momento. La producción ton/ha para el periodo 2010-2020 reflejará un aumento estimado de entre 3 y 8 ton/ha, según estos factores. Pero también se observa que de existir excedentes en el factor lluvia y pérdidas en materia orgánica, la producción tenderá a disminuir.

Palabras clave: simulación, caña de azúcar, precipitación, temperatura, materia orgánica.

Abstract

Models as simulation tools are a means to understand and explain how complex a given system can be, since the models are considered as elements available and necessary for the understanding of hypotheses involving a series of processes within these systems. A model allows real and complex situations to be generated based on simulation systems that allow decision making of any kind. This work presents support scenarios for the production of sugarcane in the valley of El Grullo-Autlán, with the support of the software VENSIM, as well as the validation of the same with the support of SPSS software (version 15.0). The results show how the soil and precipitation factors will directly and in the future affect cane production per hectare in the El Grullo-Autlán valley. In this case the quadratic and cubic model were statistically significant for the case of precipitation, but not the temperature, which is added to the history of temperatures of the last 14 years for this region, which does not present interference so far . Ton / ha production for the period 2010-2020 will reflect an estimated increase of between 3 and 8 ton / ha. According to these factors. But it is also observed that if there are surpluses in the rainfall factor and losses in organic matter, production will tend to decrease.

Key words: simulation, sugar cane, precipitation, temperature, organic matter.

Resumo

Modelos e ferramentas de simulação são um meio para compreender a complexidade de um dado sistema; elementos são considerados modelos disponíveis e necessários para compreender os pressupostos em seus processos. Um modelo pode gerar situações reais e complexas baseadas em sistemas de simulação que suportam a tomada de decisões de qualquer tipo. Este artigo apresenta, com o apoio do software VENSIM, permitindo cenários para a produção de cana no Valle El Grullo-Autlan e sua validação com o apoio do software SPSS (versão 15.0). Os resultados mostram como os factores de solo e de precipitação têm um impacto directo e o futuro na produo de cana por hectare no Valle Grullo-Autlán. Neste caso, o modelo quadrático e cúbico foram estatisticamente significativas para o caso de precipitação, não temperatura, o que aumenta a história da temperatura dos últimos 14 anos na região, que não apresentam qualquer interferência com a tempo. Produção toneladas / ha para o período de 2010-2020 irá reflectir um aumento estimado de entre 3 e 8 ton / ha, de acordo com estes factores. Mas também observa que o excedente existe no fator de chuva e perda de matéria orgânica, a produção tende a diminuir.

Palavras-chave: simulação, cana de açúcar, precipitação, temperatura, matéria orgânica.

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Introduction

The municipality of Autlán has a great agricultural activity, in which the cultivation of sugar predominates in great extensions of earth, and to a lesser extent the cultivation of corn and vegetables. The high sugar production resulting from the amount of sugarcane cultivated land makes the Valle El Grullo-Autlán one of the most productive in the country (CONADESUCA, 2015).

It is worth mentioning that this production is threatened every year by the decrease of soil nutrients, which together with the climate influences the development and growth of the crop. In addition, in recent years there has been little rainfall, causing production to be highly variable (CONAGUA, 2014).

In the El Grullo-Autlán Valley it is necessary to take radical actions regarding the proper management of land and water - irrigation and rain -, as each year the situation worsens.
Hence the need to plan and anticipate the conditions that may arise in the next ten years. The purpose of this paper is to generate strategies to help analyze the factors that affect the production of sugar cane, for example, the climate and edaphic. In this way, the organized productive sector of the region is supported: National Confederation of Rural Property (CNPR), National Confederation of Peasants (CNC) and Ingenio Melchor Ocampo (IMO), so that it benefits along with the other actors involved.

The needs of sugarcane producers, such as soil management and sugarcane production, can be met by simulating scenarios.

Literature review

Simulation is an effective way to study the behaviors given in a supply chain, as well as a practical way to understand how a complex system works, involving different actors subject to interrelated variables, which define a base behavior according to the factors Used (Liu et al., 2004).

On the other hand, the basis of a model constructed from the system dynamics is a hypothetical basic but complete explanation of a real system, which is able to reproduce the behaviors of inputs and outputs of data (Robinson, 2006, Cited in Vergara, 2008, Keenan, 2010, García, 2011). The application of systems dynamics in the agricultural field has been present in practically the last 60 years.

The application of systems dynamics in the agricultural field

As part of forage production, Holmann (2002) showed the benefits that can be obtained from the use of simulation models using as a case study the quantification of the impact of new fodder alternatives on the cost of milk production and its implications for the Technological adoption and sustainability of land use in Costa Rica and Peru.

Also, studies carried out by Vergara (2008) in the city of Bolivar in Colombia managed this tool and showed the use of dynamic networks in agroindustrial production chains, as complementary to the study based on the evaluation of possible scenarios that support the development regional.

Also in Colombia a simulation of scenarios was presented, which allowed to identify probable alternatives of management in the hortofrutícola heading. This study summarizes an arduous work of modeling the most important horticultural production chains of the department of Bolivar through the simulation of networks (Fontalvo et al., 2009).

With regard to crops, Hernández et al. (2009) reviewed the different models of simulation for the generation of scenarios, taking them as a useful tool in the decision-making processes, to be able to achieve later applications as a first approximation of the productive capacity in different edaphoclimatic conditions. Their conclusions were that these models constitute a very useful tool to be able to develop an efficient agriculture, from the economic point of view, nevertheless, perhaps it is more important to make a rational use of the natural resources, taking into account the conservation of the environment And, above all, the land resource.

Similarly, in the agricultural sector, Nicholson (2005), quoted by Keenan, (2010), suggested that modeling of system dynamics could be an effective mechanism for assessing complex problems in international rural development contexts.

In addition, with regard to the simulation in sugar cane, Aguilar et al. (2010) mention the management of scenarios from a general perspective and not as software management, that is, they propose that, according to the quality and quantity of each one of the existing facilities in Mexico, the production of Each one of them, especially when the tendency is the production of biofuels through this and other crops.

These authors also point out that low-yield mills should be integrated into the production of biofuels, those of medium production to that of sugar and biofuels, and those of better quality solely for the production of sugar. This is a reasonable proposal taking into account the global demand for biofuels and the shortage of hydrocarbons caused by the depletion of oil fields.

Systems Engineering is one of the most useful tools in scenario generation and decision making. This is pointed out by Fontalvo et al. (2010) when they expose that the simulation allows to experiment with a model, which is a simplified version of a real system. It should be clarified that the simulation is not a tool of forecasting, but rather one for the creation and validation of scenarios.

In this case, there are physical factors such as climate and soil, which directly influence the production of sugar cane. This climatic factor (precipitation) directly affects the soil variable, where the values of texture, pH and organic matter govern to a great extent its fertility.

The observed scenario is recent in terms of climate and soil and proposes actions for a better management of the sugarcane crop for the period 2010-2020, with the support of VENSIM software, using the variables of climate (precipitation and temperature) and soil (Texture, pH and organic matter), and its relation with the production of sugar cane (ton / ha). It also presents the validation of the model using SPSS software (versión 15.0).

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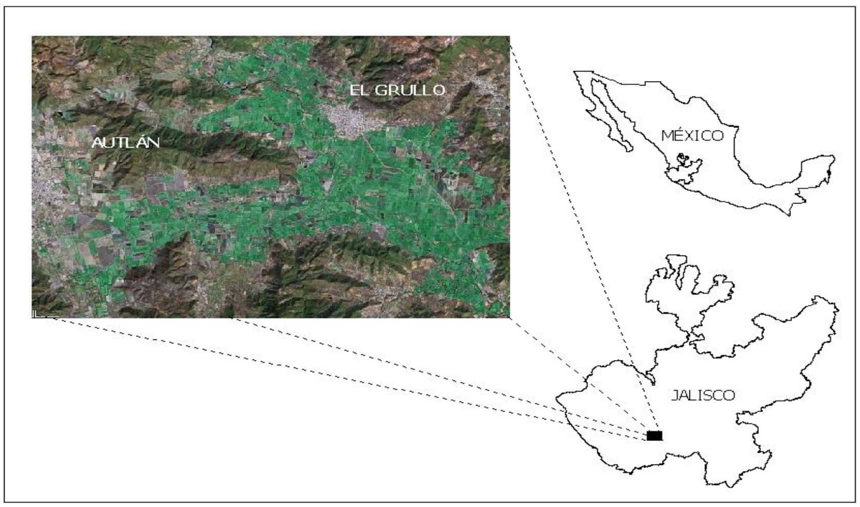
Materials and methods

The El Grullo-Autlán Valley, located in the municipalities El Grullo and Autlán (19 ° 35 'to 19 ° 54 N and 104 ° 07' to 104 ° 29 'W) (Fig. Has a mainly semi-dry climate with average rainfall of 900 mm per year and average temperatures of 24 ° C and maximum temperatures of over 32 ° C (SEI-JAL, 2000) .The soils are Feozem haplico, Fluviosol eutric, Vertisol pelicula and Regosoles in the highlands and foothills (SPP, 1981).

Figure 1. Ubicación del Valle El Grullo-Autlán (Costa Sur de Jalisco).



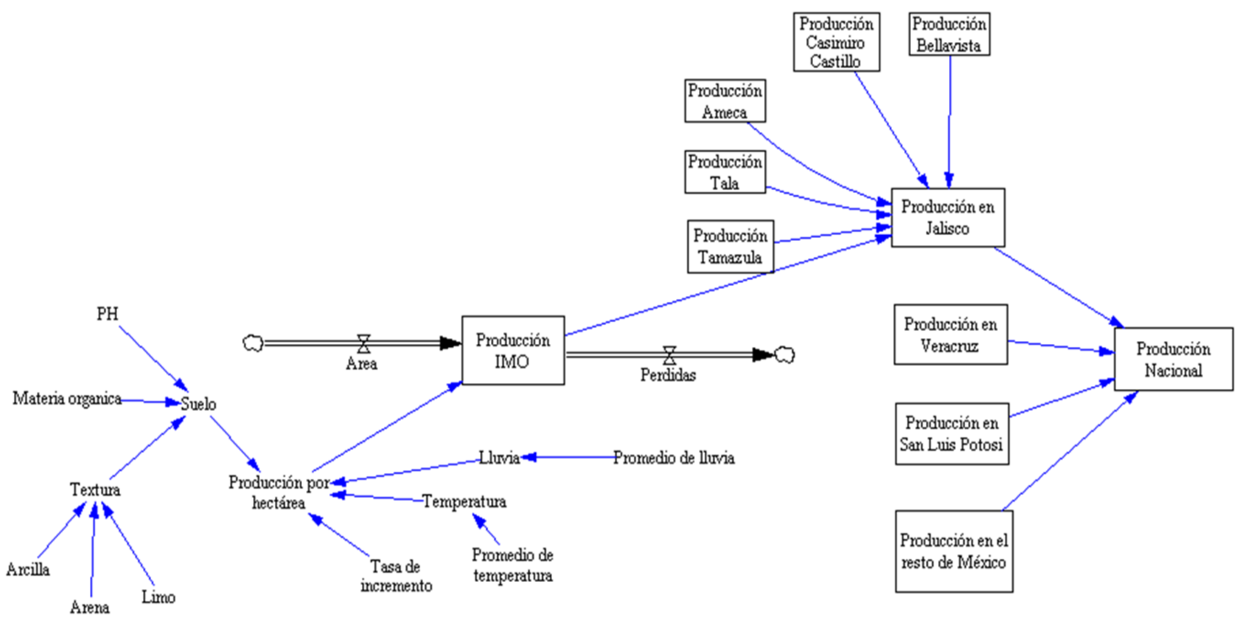
Source: Google Earth, 2014

The study also used georeferenced data on the texture, organic matter, and pH of a soil project, as well as information on the production of sugarcane (ton / ha), generated by Melchor Ocampo (IMO), and Precipitation (mm) and temperature of 14 years (2001-2014) of the climatological station El Chante (the most complete), with which the VENSIM software was fed (figure 2).

The importance of these three variables is widely recognized, as several authors point out (Acevedo et al., 2010, Ferreras et al., 2007, Lesur, 2006, Castellanos et al., 2000 and Ortíz and Ortíz, 1990) Mention that these variables are of great nutritional richness in the plots and have a potential impact on the fertility of the soils.

The data for feeding the model was given under the following context: national and regional production of sugarcane is variable and depends on the needs (demand) of the population and the stock present in storage warehouses, Which generates the supply to the population.

Figure 2. Software y desplegado de variables utilizadas para la generación de escenarios en la producción de caña de azúcar (ton/ha.) en el Valle El Grullo-Autlán.



At the national and local level, as regards the El Grullo-Autlán Valley, production depends on the guidelines that indicate the national needs based on an estimate for each sugar mill and where the cap of production is precisely that national necessity, Which determines the number of hectares to be planted with an average estimate of sugarcane / hectare / mill / year production.

Based on the above, the following values were taken for the El Grullo-Autlán Valley (until 2011):[1,2.]

World production of sugar cane was 160 948 tonnes / year (world stock), while national production of this product was 4 652 tonnes / year (national stock). The average yield for the El Grullo-Autlán Valley was: 94.21 t / ha (2010-2011 harvest). Exported: 690 tonnes / year. Imported: 900 ton / year. Sugar cane available for Mexico: total production less the amount exported plus the quantity imported: 4 862 tonnes / year. Production of sugar cane for Veracruz: 2 052 tonnes / year. Production of sugar cane for Jalisco: 573 tons / year. Production of sugar cane for San Luis Potosí: 378 tons / year. Production of sugar cane for the rest of the states: 2 376 tons / year. Average precipitation: 800 mm / year. Average temperature: 28o C. Average texture: sandy straight. Average PH: 6-7. Average organic matter: 1%.

As for the data, the production values of the last 14 years were taken from the website of the National Cane Workers Union, A.C. CNPR, as well as precipitation and temperature data provided by the National Water Commission (CONAGUA, 2014), generated at the "El Chante" Climatological Station, in the Autlán de Navarro Municipality (the most complete of this valley).

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[2] USDA (2011). *Word production, supply, and distribution, centrifugal sugar.* Sugar and Sweetener Yearbook, 2011. United States of America Department Agricultural.

[2] UNC (2011). *México en el mundo*. Unión Nacional de Cañeros, A. C.-CNPR. En: http://www.caneros.org.mx/principal.html#

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Results and Discussion

1) Software VENSIM:

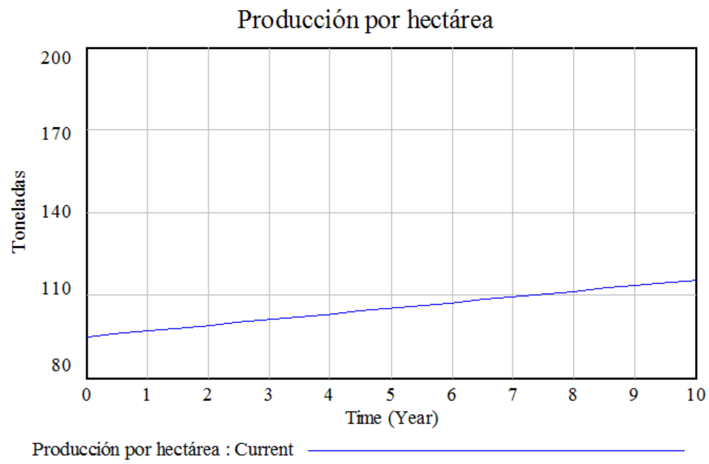
A) Variable soil: Considering the above average variables, texture, pH, organic matter and precipitation (rain), we have a "look up" whose value is one (1), as average data base for the cultivation of The sugar cane edaphic variables will be constant.

B) Precipitation variable (mm). For this variable the behavior was similar to the soil. This is that while the "look up" is kept at 1, these variables will also be constant.

C) Variable temperature (oC). For the case of the temperature, the behavior was similar to the variable soil and precipitation, although apparently this variable did not have much interference in the production of sugar cane per hectare.

D) Ton / ha production in the El Grullo-Autlán Valley. In addition to the above and as part of the current values of sugarcane production in ton / ha, it is necessary to have an average sugarcane production of 94 ton / ha and average soil As for sandy loam texture, pH of 6.5 and organic matter of 1%, the 10-year simulation (2010-2020) would be as follows (Graph 1).

Graph 1. Proyección de la producción toneladas por hectárea de la caña de azúcar (ton/ha) en el Valle El Grullo-Autlán para el periodo 2010-2020.



Graph 1 shows the trend towards a gradual increase of approximately 2 tons per year, ie, little more than twenty additional tons per hectare of sugarcane production by 2020 (average production over the next 10 years, Which may have slight variations in this period), if soil values (texture, pH and organic matter) and climate (precipitation and temperature) are maintained or slightly improved, as in the case of organic matter with the addition of fertilizers Organic.

2) *Validation of the VENSIM software model by means of regression analysis with SPSS software (versión 15).*

Simple regression models were applied through SPSS software (version 15) to determine the degree of dependence between the variables Production (ton / ha), relative to temperature (0C) and precipitation (mm). It should be noted that this was not done with the soil factor, since it does not have complete production data. The results of these models are presented below:

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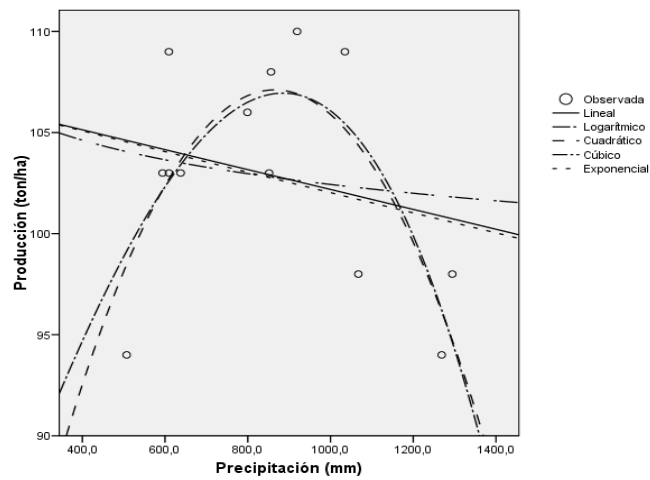
a) Production of sugarcane (ton / ha) and its relation to precipitation (mm). Regarding sugarcane production and its dependence on precipitation, the following curvilinear regression models were applied: linear, logarithmic, quadratic, cubic and exponential (Graph 2).

Graph 2. Curvilinear regression analysis for the production of sugarcane and its relation to precipitation, using the linear, logarithmic, quadratic, cubic and exponential models.



In this case, the quadratic and cubic model were statistically significant (Table 1).

Table 1. Resumen del modelo y estimación de los parámetros. Variable Precipitación (mm).

Ecuación	Resumen del modelo					Estimaciones de los parámetros			
	R cuadrado	F	gl1	gl2	Sig.	Constante	b1	b2	b3
Lineal	0,053	0,618	1	11	0,448	107,106	-0,005		
Logarítmica	0,017	0,194	1	11	0,668	118,941	-2,390		
Cuadrático	0,566	6,511	2	10	**0,015**	56,694	0,117	-6.73E-005	
Cúbico	0,541	5,889	2	10	**0,020**	73,644	0,056	0,000	-2.40E-008
Exponencial	0,055	0,642	1	11	0,440	107,175	-4.92E-005		

Variable dependiente: PRODUCCIÓN PROMEDIO
La variable independiente es Pp.

b) Production of sugarcane (ton / ha) and its relation with temperature (0C). The production of cane and its relation to temperature were estimated by a curvilinear Regression with the following models: linear, logarithmic, quadratic, cubic and exponential. In all cases, no significant regression model was found, ie there is no dependence between sugarcane production and temperature (Table 2).

Table 2. Resumen del modelo y estimación de los parámetros. Variable Temperatura (^{0}C).

Ecuación	Resumen del modelo					Estimaciones de los parámetros			
	R cuadrado	F	gl1	gl2	Sig.	Constante	b1	b2	b3
Lineal	0,068	0,807	1	11	**0,388**	44,910	2,641		
Logarítmica	0,067	0,793	1	11	**0,392**	-74,794	57,526		
Cuadrático	0,090	0,492	2	10	**0,625**	1146,787	-97,684	2,282	
Cúbico	0,090	0,493	2	10	**0,625**	434,269	0,000	-2,180	0,068
Exponencial	0,066	0,781	1	11	**0,396**	58,632	0,026		

Variable dependiente: PRODUCCIÓN PROMEDIO
La variable independiente es Temp.

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Conclusions

Soil behavior will be constant for the period 2010-2020, and as long as current land conditions are maintained, production (ton / ha) will be maintained with slight declines or elevations. Also, when the precipitation ranges are altered, the production will also be affected, thus generating a decrease of the same. With regard to temperature, it had at least for this period a very marked interference.

As for the average sugarcane production (ton / ha), the simulation showed a slight increase in order production, approximately 2 tons per year, that is, slightly more than twenty additional tons per hectare in Production of sugar cane for the period 2010-2020.

With respect to the simulation with SPSS software, and when estimating cane production and its relation to precipitation and temperature by means of a curvilinear Regression and with the models: linear, logarithmic, quadratic, cubic and exponential, it cooperates directly in the precipitation. It was observed that of all the regression models applied, only the cubic and quadratic models were statistically significant ($p < 0.05$) for the precipitation, proving that cubic and quadratic dependence exists between production and this climatic variable.

For the case of temperature, all the regression models were greater than 0.05, which shows with a 95% certainty that there is no dependence between sugar cane production and temperature.

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