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Collateral Effect of the Introduction of Ethanol in the Sugar Economy by System Dynamics

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Abstract

This paper analyzes the impacts of the increase in the demand of biofuels on the supply and prices of sugar in Colombia. The Colombian government, in order to promote environmental policies, created some incentives for the production and consumption of biofuels by mixing gasoline with ethanol. On the other hand, in the country the majority of Ethanol produced is from ground sugar cane, which causes direct competition with sugar and its derivatives to obtain the raw material. In this way, a model is formulated using System Dynamics to simulate the future behavior of Ethanol and sugar starting from ground sugar cane. The findings show that it is more profitable to use sugarcane to produce ethanol than to produce sugar.

Keywords: Ethanol, sugar, biofuels, Dynamic Systems.

INTRODUCTION

The global demand for biofuels has increased in recent years. Currently, many countries have implemented policies and programs that encourage the production, commercialization and distribution of these biofuels. In Colombia the most used biofuel is Ethanol, which can be extracted from various agricultural products, but the predominant one is sugar cane. Sugar cane and its derivatives are produced from sugar cane, as well as ethanol. The same sugar mills and their derivatives also produce ethanol; they have seen the growing demand for this biofuel as well as its good profitability.

In this way, Colombian policies with the objective of using alternative energy sources such as Ethanol for transportation, has generated an increase in the industry of biofuel production and in the agricultural industry due to the increase in areas cultivated for this purpose. As a result, sugarcane growers tend to grow cane for Ethanol production and not for the production of sugar and its derivatives. This has caused the production of sugar to be affected by the shortage of raw material (ground sugar cane) which in turn increases the price variations in the market of this good of the family basket.

On the other hand, biofuels are the substitutes for fuels called fossils, petroleum derivatives. These substitutes, such as Ethanol, come from renewable sources and are used against the deterioration of the environment, for this reason the interest of mixing these biofuels with gasoline. The mixture of Ethanol / gasoline in a proportion of 10% / 90% respectively contains 3.5% more oxygen than unmixed gasoline, which leads to a decrease in nitrogen oxide emissions [1].

The method of modeling and simulation of Systems Dynamics, was developed for the first time by Professor J.W. Forrester in 1950 to analyze complex behaviors in the social sciences by means of computer simulations [2]. Prior to System Dynamics, decisions made to address a problem often yielded unexpected results; hence the need to develop a new methodology [3]. The System Dynamics approach is used to describe and model the activities of complex systems over time. System Dynamics uses the various control factors of the system and observes how the system reacts and behaves to trends. Therefore, System Dynamics can be used to help decision-making when the target systems are complex and dynamic [4].

The main objective of this research is to determine the collateral effects that can be generated by the production of ethanol from sugarcane, since in Colombia it is the most used for this purpose since 2005, being sugarcane also used for the production of panela, molasses and sugar among others, the production of ethanol displaces or leaves to some extent the cultivation of cane for the production of primary goods, in this case it can be shown that the mass production of ethanol would produce direct competition with sugar and its substitutes. For the realization of this study, only the effects related to sugar and ethanol will be taken.

Then we describe the problems of this work starting from the Colombian political trends to sugarcane growers. Subsequently, the two basic tools to deal with this issue from the Dynamics of Systems will be announced, which are the causal diagram and the flow and level diagram. Then the results of the simulation will be shown followed by the validation of the model, which indicates a degree of reliability of the same. Finally, the results as suggested public policies to the problematic posed.

Research problem

The environmental problems related to the combustion of hydrocarbons, have placed the world to think about other types of fuels that are friendly to the environment; hence the idea of producing fuels and biofuels, also called clean fuels that mitigate the environmental impact generated by traditional fuels.

Colombia has not been reluctant to change, on the contrary, it has had good acceptance and has developed mechanisms and policies that allow it to adapt and mix traditionally derived petroleum fuels (gasoline and diesel) with clean fuels

(Bioethanol and Biodiesel). Colombia is currently considered the second largest ethanol producer in Latin America, which places it in a good place to cover the demand for fuel alcohols; Nevertheless; they are products derived from staple crops such as corn, sugarcane, yucca, and beet.

From 2001 the Congress of the Republic approves the law 693 that establishes the normativity in the use of biofuels and a program of incentives that promote the production, to the 2008 already 65 billion pesos had been invested in this program so much for the producers as for researchers, which has caused the Ethanol production to increase year after year; But even with these increases, the total demand for ethanol for the requirements established by the government to oxygenate 10% of gasoline in the main cities of the country is not covered in its entirety, which leads to the conclusion that the conviction the ministry of agriculture as a goal (to exceed that 10% by 2012) can be met without significantly affecting the price and production of sugar. In addition to the above, the demand for Ethanol also increased after Law 1083 of 2006 when it was approved that public service companies that had an impact in metropolitan areas would have to use clean fuels.

According to the Sugar Cane Growers Association of Colombia to cover the total demand of the seven main cities, it is necessary to have an amount of 5.93 million tons of sugar, which would be equivalent to cultivating 74 thousand hectares of cane. sugar, on the other hand it is necessary to comply with the current demands of white sugar from the family basket by cultivating around 18.1 million tons of sugarcane which is equivalent to cultivating 182,689 hectares; although it is true that Colombia has great arable potential to meet the internal demands of both ethanol and sugar and byproducts since it has an area of 3,898,583 hectares for this purpose, it must be borne in mind that not all of the If the land is being used, then the question is: to what extent is it possible to increase the Ethanol mixture above that 10% without affecting the economy and maximum production capacity of the sugar?

With the expectations of the government, the time horizon that can be considered for the study of this model is 10 years, since by 2020 it is expected that fossil fuels in Colombia will have a maximum oxygenation of 25%, which would mean a great feat on the part of the growers of sugarcane and a greater use of the potential of sowing with which the country counts to be able to supply this great demand.

MATERIALS AND METHODS

Dynamic hypothesis

To provide a solution to the previous approach, the System Dynamics is chosen for its ease in describing problems that are persistent and recurrent behaviors. System Dynamics is a systems simulation methodology based on feedback and information delays, for the modeling and simulation analysis of complex problems centered on the analysis and design of policies. The methodology consists of flow diagrams and levels and causal diagrams. The latter represent the causal hypotheses of a system and the flow diagrams and levels represent the flow structure of the system. Mathematically S (t) represents the level at time t, the flow or inflows and the flow or outflows denote the input and output values at any time S (see equation 1) [5].

$$S(t) = \int_{t_0}^{t} (cash\ flow\ input - cash\ flow\ output) ds + S(t_0) \quad [1]$$

On the other hand, the flow variables describe the exchange rates. Thus the levels change according to the net flows. In turn, the net flows are equivalent to the rate of variation of the levels according to equation 2 [5].

$$\frac{d}{dt}(S) = cash\ flow\ input_t - cash\ flow\ output_t \qquad [2]$$

System Dynamics is applied in a series of practical problems, including corporate planning, policy design, policy evaluation, supply chain management, public management, economic behavior, among other issues [5], [6]. System Dynamics is a simulation methodology for the understanding, visualization and analysis of complex dynamic feedback systems. It can be used to understand the behavior of complex systems over time and to develop the simulation model of a complex system. In general, it involves aggregate levels of detail and deals with internal feedback loops and delays that affect the behavior of the entire system. What makes the use of System Dynamics different from other approaches to study complex systems is the use of feedback and stock and flow circuits. These elements help to describe how even seemingly simple systems show disconcerting non-linearity [7].

System Dynamics is a simulation methodology for the analysis of dynamic complexities in socioeconomic and biophysical systems that have characteristics such as delays, non-linearities and feedback [3]. Based on the principle of systemic thinking and the theory of control systems, System Dynamics helps to understand the behavior over time of complex systems.

The problems with the introduction of ethanol into the market and the sugarcane economy generate cyclical problems of production based on the profitability that are evident in the causal diagram of figure 1.

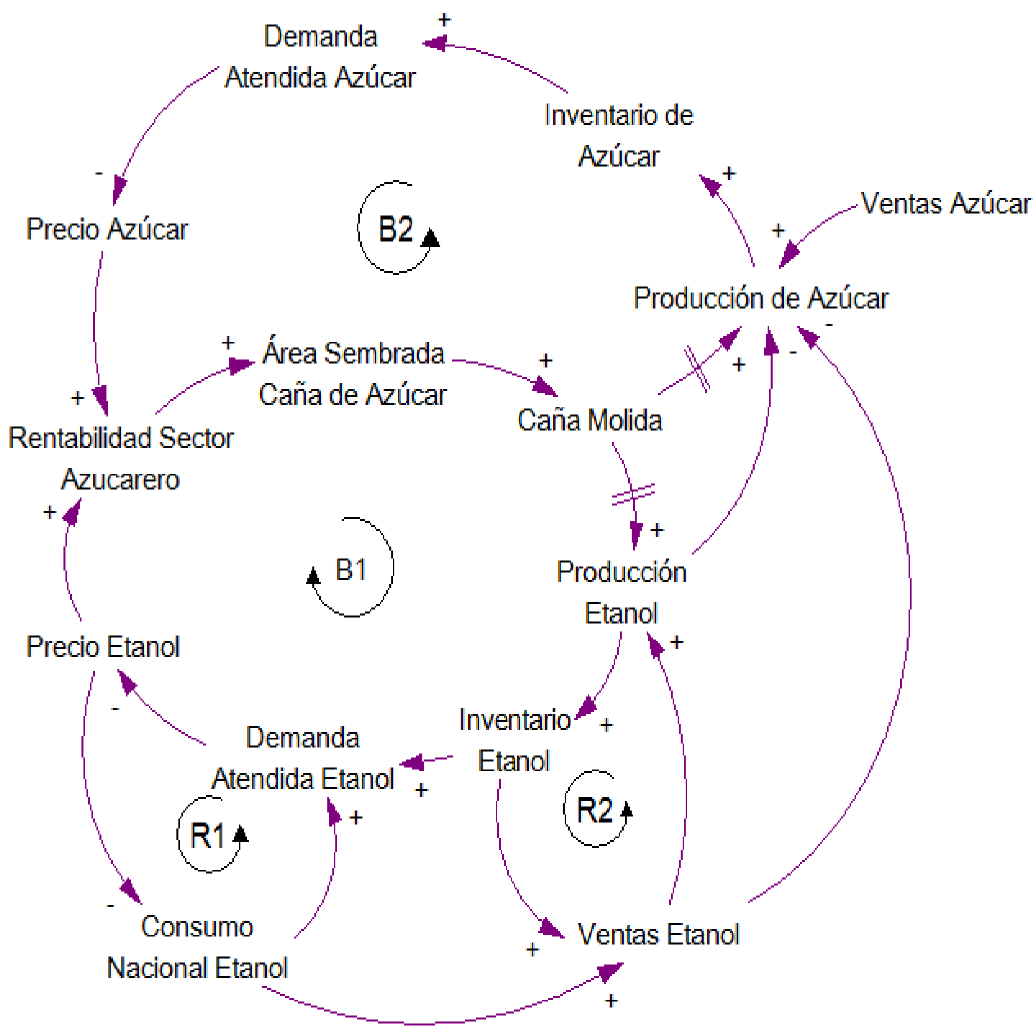

Figure 1. Causal diagram.

Where,

Área Sembrada Caña De Azúcar: Area planted with sugar cane

Caña Molida: Ground cane

Producción etanol: Ethanol production

Inventario Etanol: Ethanol inventory

Demanda Atendida Etanol: Demand met ethanol

Precio Etanol: Ethanol price

Rentabilidad Sector Azucarero: Sugar sector profitability

Producción de Azúcar: Sugar production

Inventario de Azúcar: Sugar inventory

Demanda Atendida de Azúcar: Demand for suga

Precio Azúcar: Sugar price

Ventas Azúcar: Sugar sales

Consumo Nacional Etanol: National ethanol consumption

Ventas Etanol: Ethanol sales

As a starting point in Figure 1 it is observed that the higher the profitability, the greater the investment, because of the attractiveness that a higher rate of remuneration generates in any type of business, similarly in the sugarcane crops, the same thing is observed, since more crops, the production of ground cane also increases; because the two products (Ethanol and sugar) are supplied from the same point, it is divided for the production of sugar and for the production of Ethanol. The increase of these two products causes a greater demand attended to each one, which causes the price to decrease due to the excess supply that is analyzed with a larger inventory because of the laws of supply and demand it is known that all good abundant rebate its price.

In figure 1 it can also be seen that the model has four cycles, B1 and B2, corresponding to balance cycles that are integrated to see the behavior of sugar and ethanol, respectively. The cycle of balance B2 has as variables the profitability of the sector, the area planted with sugarcane, the milled cane that has a delay to continue with the production of sugar, then the sugar inventory, the attended demand for sugar and finally its price. On the other hand, cycle B1 is composed of the first three variables of the B2 cycle since the processes of elaboration of both start from the same productive chain, the production of Ethanol is the next variable in the cycle that is also established by a delay in the previous variable, continuing then with Ethanol inventory, ethanol demand and price. There are also two reinforcement cycles R1 and R2, the first represents the national consumption of Ethanol and the second the national sales that help reinforce as its name indicates the cyclical situation of sales with respect to production, ie, the more Increased sales are increased production; in the case of consumption, the same happens when increasing them also increases the demand served.

The collateral effects that are to be described in the case study are represented between the sales of Ethanol, the production of Ethanol and the production of sugar, that is, it is observed in the causal diagram that there is a greater proportion in sales of Ethanol This becomes attractive to produce, which would put aside the production of sugar, also as already stated, the production of sugar and ethanol come from the same source as there is a greater production of Ethanol, the production of sugar would also decrease, which would cause, on the one hand and part, an increase in the price of sugar due to the effects of the laws of supply and demand.

Model flows and levels

Figure 2 shows the flow diagram and levels which is the support for the simulation.

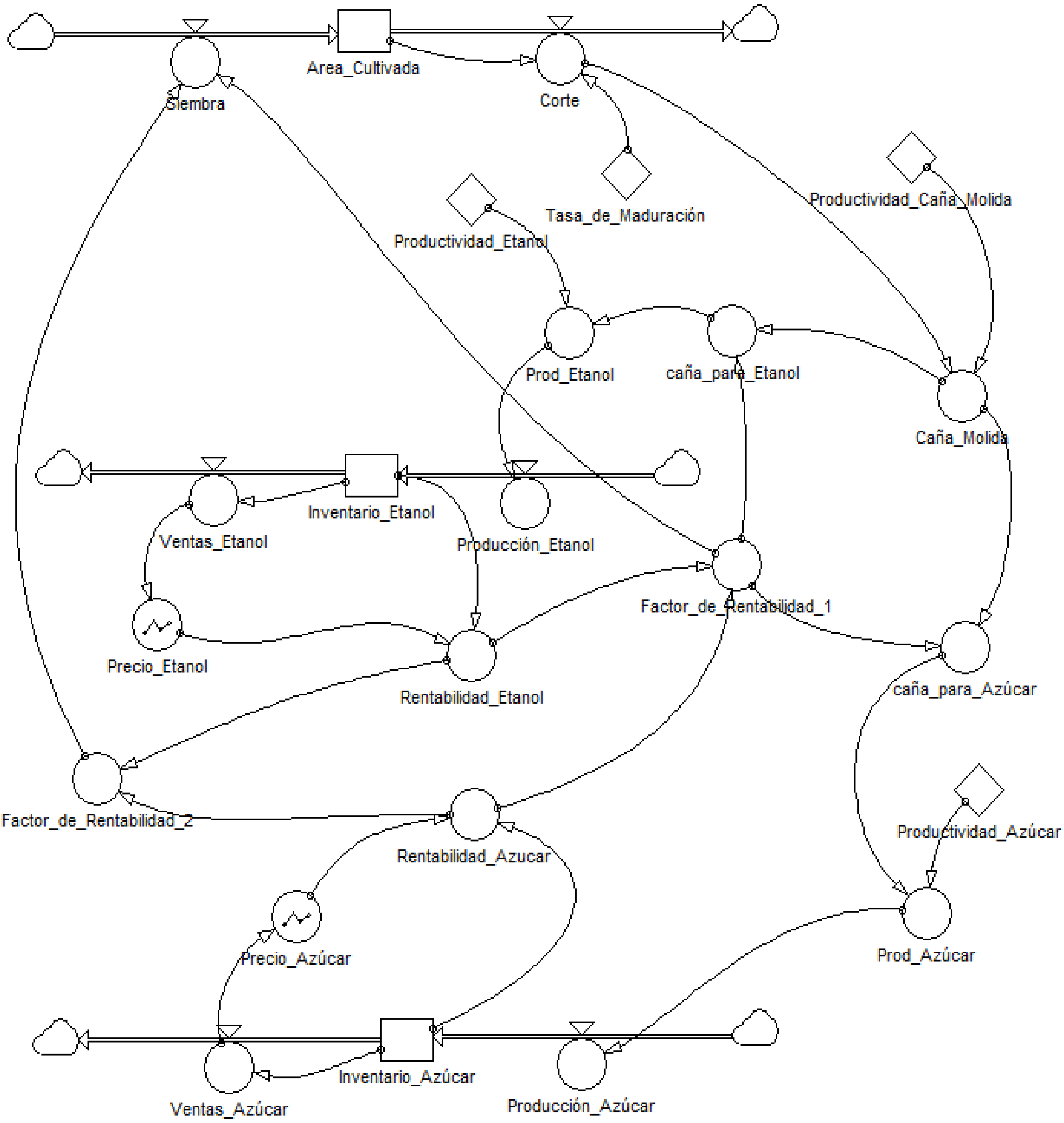

Figure 2. Flow and level diagram.

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RESULTS AND DISCUSSIONS

Due to the introduction of Ethanol, the sugar inventory is affected, Figure 3 shows this behavior because the initial production in the present is at an average of 2.1 million tons per year. Throughout the 10 years of the simulation it is observed that the production begins to fall, continuing with this tendency, supplying the internal demand of sugar would become a general problem, because currently the domestic market demands around 1.6 million tons.

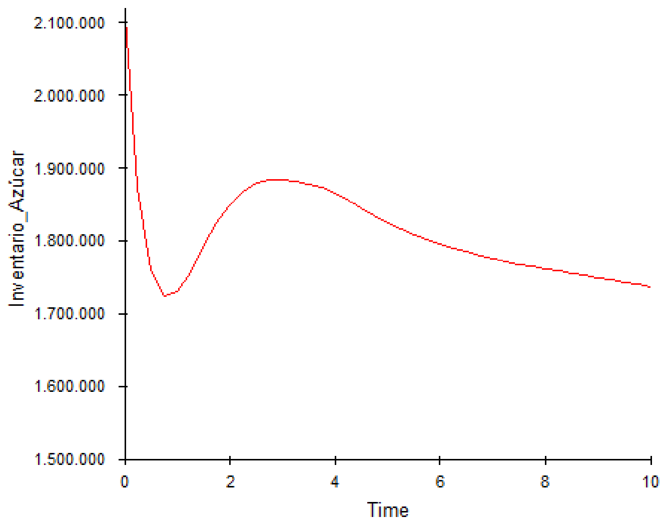

Figure 3. Sugar inventory.

While the production of sugar goes down, figure 4 shows that, on the contrary, ethanol tends to grow in an accelerated way, thanks to the incentives granted by the government, trying to replace the goals stipulated by it. The simulated model shows the difference in profitability (figure 5), Ethanol has a higher profitability which makes it more attractive to produce cane for this purpose and that increases in planting are determined by said profitability. The red line represents the profitability of sugar and the green line the profitability of Ethanol.

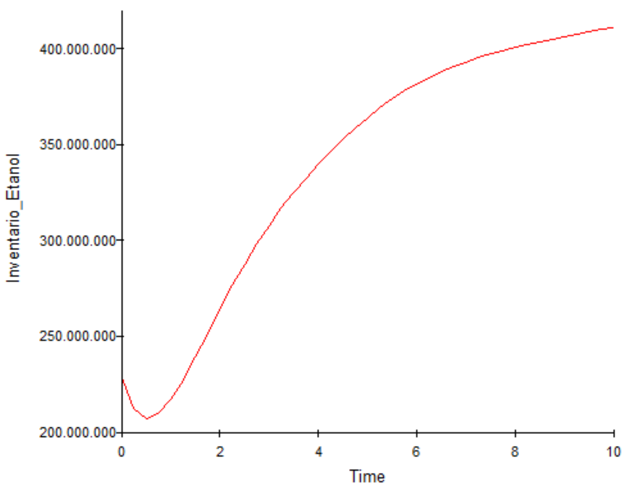

Figure 4. Ethanol inventory.

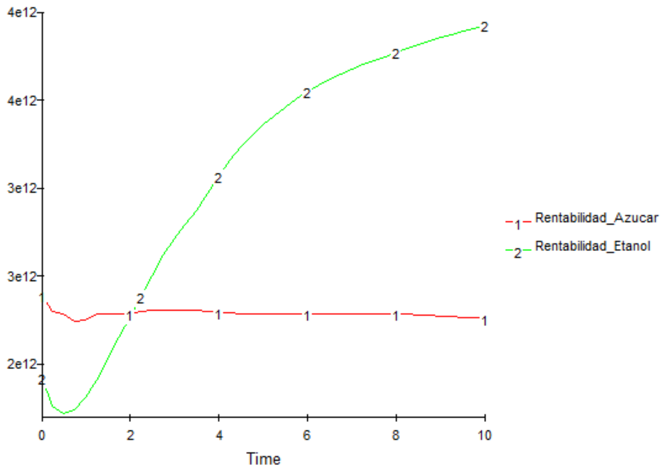

Figure 5. Profitability of Ethanol and sugar.

The prices of both ethanol and sugar are variables of interest for the model because they are also capable of explaining what would happen to the economy of the cane. For its part, ethanol is considered a price with a positive trend because it is a highly demanded and little produced product that in turn is marked by the gasoline economy that historically has maintained this behavior (see figure 6). Sugar, being a commodity good too, has had an oscillatory historical behavior; However, the model shows that the price of this tends to rise due to the scarcity that begins to present with the increase in the supply of Ethanol (see figure 7).

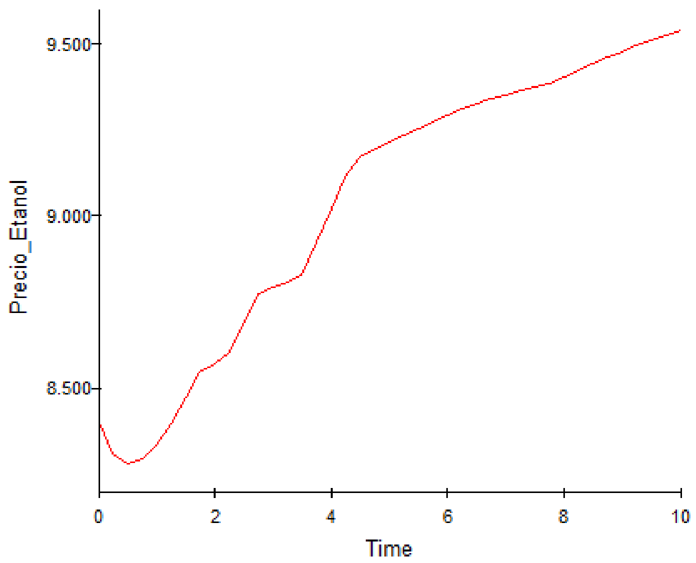

Figure 6. Ethanol price.

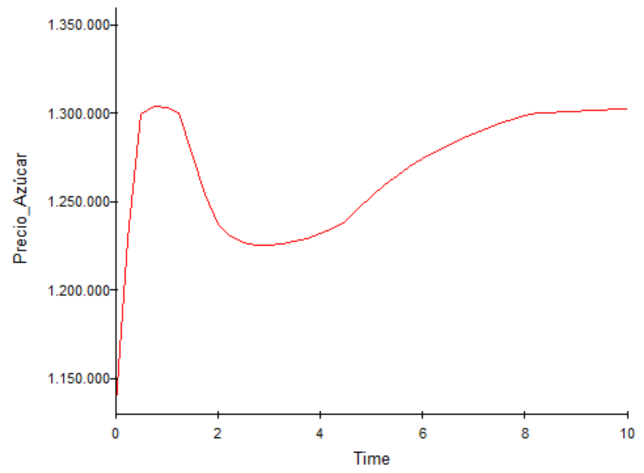

Figure 7. Price of sugar.

Finally, according to the model for the next 10 years, the cultivated area of sugarcane will be around 350,000 hectares per year as can be seen in figure 8, which is a figure lower than what is available in Colombia for this end that are around 3.8 million hectares.

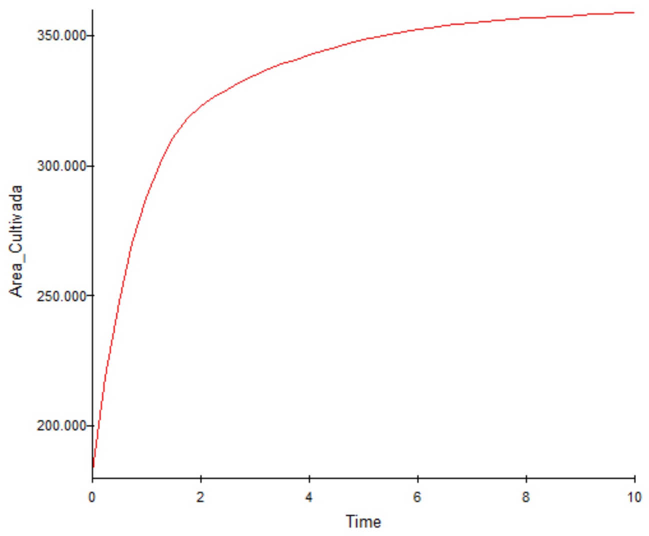

Figure 7. Cultivated area of sugar cane.

Validation of the model

Model limits test

The model used to show the behavior and visualize the collateral effects of the introduction of anhydrous ethanol, derived from sugarcane to the biofuels market, has as main constraints:

- Laws that have been implemented regarding the oxygenation of gasoline in all the major cities of the country. There is an ambitious goal by the government to oxygenate gasoline to 25% in the main cities by 2020.
- The substitute and complementary goods of the sugar are not taken into account so as not to extend beyond what is really wanted to model, the behavior of the sugar, given the introduction of Ethanol.
- The production costs of both sugar and ethanol must be left out of the model due to lack of information, as these are generally controlled by each of the sugar mills in the country and depend on their productivity, which makes very difficult to collect the data by secondary sources of information.
- The time horizon delimits the model to 10 years due to the government's expectations of encouraging the increase in ethanol production until 2020 with a high oxygenation in gasoline. Beginning then the simulation in 2012 and ending in 2021, because the data with which the model was calibrated were only found until 2011.

On the other hand, it was found that the most important issues in the model were considered within its structure, none of the variables described in the dynamic hypothesis approach stopped being considered, these variables were: sowing, amount of ground cane , the production of Ethanol and sugar, the inventories, the demands, the price and the profitability of each one, as well as the sales of Ethanol that are assumed within the assumptions of the model as a highly demanded good, since everything that is produced , 100% is sold; determining then that these variables are endogenous. Ethanol exports are not taken into account; However, to determine the production of sugar exports are taken as an exogenous variable because it is a good that is produced abundantly in the country and it is necessary to meet the internal demand to find an outlet to avoid accumulations.

Structure evaluation test

The model used is consistent in accordance with Marshall's law of supply and demand, according to Nicholson [8] the prices reflect both the marginal value that the plaintiffs grant to the goods, and the marginal costs of the production of the same. In a few words, it determines that the two curves that determine the equilibrium price are those of supply and demand, for which if the demand curve is analyzed, the higher the price the lower the quantity demanded of the good. Following then the law described, it is determined that the sales of both products are limited to this under a graphic variable that determines the behavior of the price depending on the sales to which they are assumed as demand.

Dimensional consistency test

Both the units of the variables and the results of the equations are consistent, which gives an indication that there are no problems in the formulation of the model.

Extreme conditions test

In this test a simulation was made with initial values in zero for each of the levels (Cultivated Area, Ethanol Inventory, Sugar

Inventory) which resulted in that nothing was produced which is in accordance with reality. At the other extreme, it was simulated with a productivity 1000 times greater than the milled cane, which resulted in the fact that it is more efficient to produce ethanol and sugar, this is evidenced in figures 9, 10 and 11 where it was obtained that the inventories of ethanol and sugar were quite high with a small increase in the cultivated area with respect to the initial graphs.

In summary, no flaws were found in the model faced with simulated extreme variations, the model reflects a behavior equal to that of reality under those conditions.

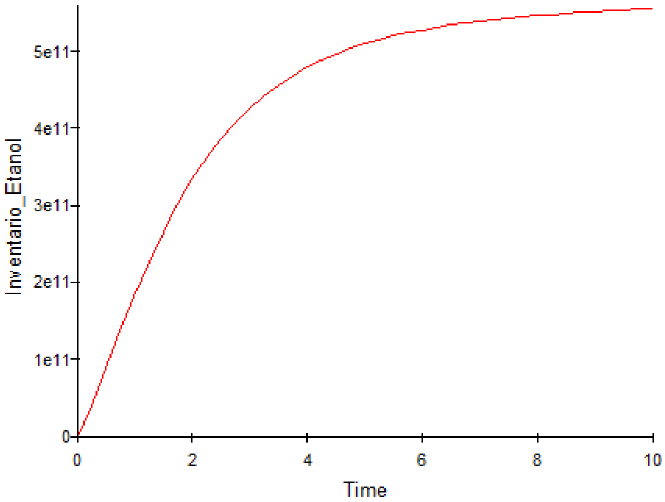

Figure 9. Ethanol inventory.

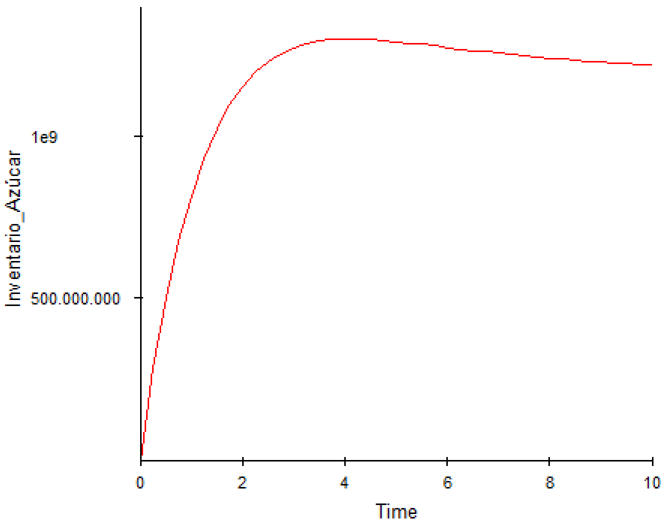

Figure 10. Sugar inventory.

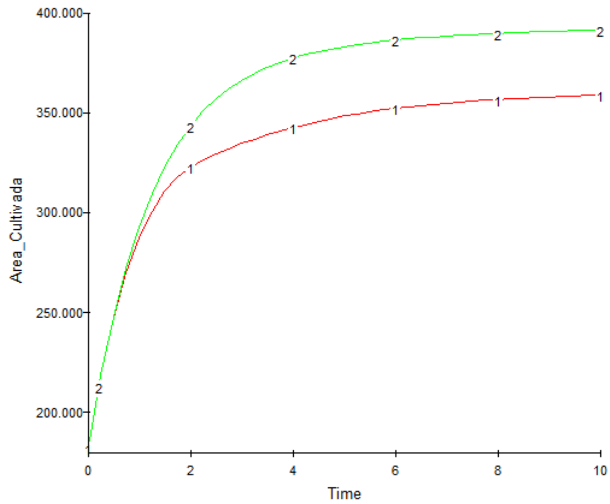

Figure 11. Cultivated area.

Behavior reproduction test

The model is behaving according to what was expected in the definition of the problem: the introduction of Ethanol to the market displaces the production of sugar due to its high profit margins. In addition, Ethanol production both in the simulated model and in reality has an increasing behavior because it is in its growth stage in Colombia.

CONCLUSIONS

The final results of the model show a discouraging proposal for sugar production in the long term due to the collateral effect of the introduction and the assured growth of ethanol, which could affect supply to supply domestic consumption and exports; According to the 2022 simulation, sugar production will be around 1.7 million tons per year given that it currently stands at 2.1 million tons for both markets.

Currently ethanol has incentives from the government to support production, due to this growth since 2005 (which was its introduction) has been accelerated so far, according to the data provided by the model if the displacement of sugar, without counting any other derivative of the cane, would be inevitable. To avoid a disaster in the sugar economy like the one that has already been raised, several strategic alternatives are offered with which the government can count.

1. A law or decree that intervenes on Colombian mills could be issued so that the internal demand for sugar is fulfilled as a minimum and in the first instance. A policy like this would stop the supply deficit, but it would not assure that the price of this would remain stable, so that accompanying this law, a price control must be carried out in order to generate a protectionist policy to guarantee the welfare of the final consumer.

2. At the time that the decline in sugar production can be visualized, incentives can be implemented to encourage sugar mills to produce again the quantities needed for both the domestic and foreign markets, in this way and without restricting ethanol both could grow without the need to move the one to the other, this must be done taking into account the

maximum capacity produced that until now with the final data of the simulation do not reach to occupy the maximum extension of hectares with which Colombia has for this purpose.

3. Create incentives for the use of areas suitable for the cultivation of sugarcane in Colombia. In this way, an efficiency in the use of the land would be achieved, which would prevent the shortage of ground cane in the country to compete for ethanol and sugar.

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