UNIVERSITÀ DEGLI STUDI DI PALERMO

Model Based Public Planning, Policy Design and Management

MODELING PUBLIC POLICIES ANALYSIS OF LOGISTICS COLLABORATION IN THE PERFORMANCE OF THE AGRICULTURAL SECTOR OF THE POTATO IN COLOMBIA

PhD. Candidate

Olga Rosana Romero Quiroga

Doctoral Thesis Supervisor
University of Palermo
Carmine Bianchi

Doctoral Thesis Supervisor
National University of Colombia
Gerard Olivar Tost

CYCLE XXXII

2020

A mi esposo e hijos, lo logramos...

Agradecimientos

En esta etapa, no me queda más que agradecimientos a quienes de diversas formas, todas ellas invaluables, compartieron conmigo el transcurrir de un camino diverso, muchas veces confuso, extenuante, pero al final y aunque pocos lo pueden comprender, profundamente enriquecedor, entre lecciones de terquedad y humildad.

Al profesor Carmine Bianchi, por su gran ejemplo, su calidez y humildad al compartir abiertamente todo su trabajo y conocimiento, con aportes justos cuando las bases apenas se estaban cimentando.

Al profesor Gerard, por su precisión, por sus aportes llenos de experiencia, por su inagotable cercanía e interés, por su sinceridad llena de valor y de dirección.

A Cristian Trejos, por cada comentario, cuestionamiento, dedicación y acompañamiento.

A Suppla, que siempre ha significado un gran reto para mí y que me ha dado la oportunidad de creer y de hacer; muchas gracias al ingeniero Robinson Vásquez por su genialidad y competitividad y a Claudia Bedoya por su entrega y enseñanzas.

A Stephen Martin, por la generosidad de su tiempo y dedicación, muchas gracias por cada aporte y cada corrección.

A cada uno de los campesinos y productores, que entienden la importancia de la tierra y de su fruto, que no desfallecen y que son fuente inagotable de humildad, gracias por compartirme un poco de su sabiduría, todo mi orgullo y respeto para ustedes.

Agradezco a toda mi familia, a mi mamá, mi papá, mi hermana, cuñado y sobrinos, sin ellos no hubiera sido posible este logro, por su acompañamiento incansable, quienes vieron gestar este gran esfuerzo, pero sobre todo porque acompañaron a Miguel cuando su mamá escasamente lo podía hacer.

A mi esposo Mauricio e hijos Samuel y Miguel, por su fortaleza y paciencia. Aunque a lo largo de este proceso muchas veces cuestioné mi papel de mamá, esposa, profesional y académica, debo decir que más allá de eso lo verdaderamente relevante es que ustedes fueron mis cómplices y me dieron la posibilidad de fallar y continuar.

A Mauricio mi mejor socio, muchas fueron las discusiones, días largos y extenuantes, que tejieron poco a poco no solo el resultado de nuestro trabajo, sino de las personas que somos.

LIST OF CONTENTS

LIST OF FIGURES

Chapter 1: Dynamic performance of the agricultural sector under conditions of climate change and armed post-conflict

Chapter 2: Modeling collaborative logistics policies that impact the performance of the agricultural sector

Chapter 3: Guidelines for collaborative public policy in the agricultural sector, based on the analysis of dynamic sensitivity

ABSTRACT

Background

The agricultural sector is considered fundamental for the supply of food needs of humanity, given the population growth. According to the Food and Agriculture Organization FAO [1], the world population is estimated to be 9 billion people by the year 2050 and where the conditions of climate change can decrease crop yield up to 25% [1] [2]. This triggers greater vulnerability to the neediest population, being the rural sector the one hosting the poorest people.

The rural area of Colombia represents 94% of extend the national territory [3], where 24% of the population lives a scenario of multiple problems that affect the country, such as the armed conflict of more than five decades, the presence of illicit crops and social inequality. Proof of this is that 0.4% of the Agricultural Production Units (UPA) have 41.1% of the total rural area registered by the National Administrative Department of Statistics DANE [3].That is, the land is the property or responsibility of a single producer natural or legal. The concentration of land leads to factors of inequality, where 41.4% of the population is in conditions of poverty and 18% in extreme poverty [4].

These factors deteriorate given the low productivity, where about 36 million hectares are dedicated to livestock production and could have agricultural or forestry use, generating speculation in prices and a greater concentration of land and wealth.

In Colombia, of the total of the rural area (excluding natural forests) only 12.7% goes to crops. Approximately 7.12 million hectares have agricultural vocation and whose production supplies the basic food needs of about 70% of the total of the Colombian population [5], mostly from small and medium-sized farmers [6].

An exponent of colombian agriculture reality and whose production allows the livelihood of millions of people, is the agricultural sector of the potato. The potato is the object of study of this research and whose origin goes back to the Andes mountain range of South America. 7000 years ago, the wild plant was traded around the Titicaca river and began its process of domestication by hunters and gatherers who inhabited the area. Later, around the year 1400 the Incas improved the agricultural advances of their predecessors, where as well as corn, the potato was essential to make sure the food security of their empire that stretched from what is known today as Argentina to Colombia. With the Spanish invasion, the Inca civilization ended, however, the same did not happen with the potato, which spread to Europe between 1532 and 1572, where the aristocracy admired the potato flower but considered it a food not suitable for human consumption. Towards 1770, continental Europe was hit by famine, which opened the way to recognize the potato as a high-value food and food security. From that moment and during the nineteenth century it helped to meet the demographic growth of Europe, the United States and the British region [7].

This is how the potato presents a strong global expansion, occupying the fifth place of the staple foods of higher production, after sugarcane, corn, rice and wheat, where its world production is estimated at 368 million tons per year [8]. In Colombia, 80% of the cultivated area corresponds to agro industrial crops, tubers, bananas and cereals, which together represent 63% of agricultural production [3]. The potato is the fourth product of greater national production [9] and the second when excluding the products of the agro industrial group, such as sugarcane and palm oil.

During the last decade, the cultivated area decreased 2.51%. The yield only increased by 0.84% and the production fell 1.69%, behaviour opposite to the growth of the population, which in the same period was 1.32%. The yield of the crop in Colombia, is estimated between 15 and 17 tons per hectare cultivated, a low performance compared to the average presented by the countries with higher productivity, such as Belgium (45.3 tons / ha), New Zealand (45.1 tons / ha), Holland (43.8 tons / ha) and the United States (42.1 tons / ha) [9]

In Colombia around 90,000 families [10] are directly related to the production of potatoes, corresponding to 44,966 agricultural production units (UPA) and where the departments of Cundinamarca, Boyacá and Nariño represent 85.3% of national production [3].

According to the amount of hectares planted, the producers are classified as small, medium and large [10], where the small producer's share represents 90%, with land up to 3 hectares and which generates 45% of the production. Followed by the medium producer with a 7% share, planting between 3 and 10 hectares and 35% of the production. Finally, the large producer with extensions of more than 10 hectares, represents 3% of the producers generating 20% of the production. This is how small farmers have a fundamental role in national production, despite restricted access to technology and better agricultural practices.

The potato presents seasonality in its production, depending on the rainy season due to absent artificial irrigation systems, the in elasticity of the demand for prices [11] , and the lack of proper storage systems. This facilitates an unbalanced environment between supply and demand, reflected in a high volatility of prices to the detriment of the producer and which, when added to the high costs of the crop, generates low financial returns. These are reflected in the investments made in hectares cultivated in the next period [12].

These characteristics highlight the need to transform the countryside. They seek to strengthen agricultural competitiveness to consolidate the sector as a generator of employment and wealth for rural inhabitants. These requires comprehensive interventions in territorial planning, provision of public goods and social services, productive inclusion of the farmers, as well as develop mechanisms that bring small producers closer to the city markets.

The above frames the challenge of infrastructure as a trigger of develop the field, to reducing transport costs and improving the conservation of products along the logistics chain. Precisely the deficient quantity and quality of infrastructure has generated the appearance of a large number of intermediaries in the supply network, weakening the commercial position of the producers [13].

On the other hand, the low-level of associativity of Colombian agricultural producers, which according to the national agricultural census of 2014, shows how 73.7% of producers declare not belonging to any association or union [3]. This reduces the possibility of access to best practices that improve their conditions, and reducing the potential of their competitiveness and positioning in the logistics network. Through greater synergies, reflected among other aspects, in costs, opportunity and innovation, that is, it produces a greater capacity of the process to serve increasingly dynamic markets.

This is how in recent years, and as it has been defined in various world forums, the international community has reaffirmed the need to formulate agricultural strategies that allow its sustained growth and that address develop the rural population. However, despite the interest collective and given the diversity of conditions surrounding agricultural development, it is not enough to stick to traditional policies such as import controls, subsidies or credit policies, among others. That is why this research addresses agricultural development from a perspective of collaborative logistics. In addition to encouraging develop the producer, this allows us to consider global realities such as climate change, the growing need for food, the increase in population and the volatility of the prices of food, which together threaten the food security of nations and where Colombia can play a strategic role, thanks to its natural characteristics, but which need policies and actions to achieve it.

This implies the need for developing strategies to face these challenges, considering disintegrate the processes as an over effort among the members of the logistics network, with collaboration as a driving force for competitiveness in value chains being fundamental.

The integration of agricultural logistics processes depends directly on the aggregate planning of supply chain requirements and this is where this research recognizes the distribution centers, as central nodes of the network, by directly influencing the planning and development of other logistics activities. These include : the supply of materials and supplies, inventory management, co-packing, added value processes and planning to distribute merchandise, as well as a mediator between the producer and the consumer.

In this way, for logistics networks, the challenge arises when balancing the variability of supply and demand conditions with capacity models. To reduce uncertainty in decision-making, in a sector that in addition to technical assistance to improve crop yields, this also requires the formulation and implementation of public policies that encourage better logistical practices to trigger greater producer development.

This research has the purpose of analysing the dynamic performance of the agricultural supply of potatoes in Colombia and the incidence of horizontal collaborative processes in distribution centers. This allows defining guidelines to formulate public policies for improving the performance of the rural sector, measured through production costs, crop yield and financial gross margin obtained by the producer.

To do the purpose stated above, the problem is addressed through the different chapters, where the first chapter is based on the modeling of the agricultural sector of the potato. This integrates parameters of previous studies associated with the possible effects of the armed post-conflict in the target country and the effect on the crop in conditions of climate change, allowing the generation of diverse scenarios, contrasted through performance measures.

Subsequently, in the second chapter, public policy scenarios that impel collaborative relationships between producers through specialized logistics infrastructures, such as distribution centers, are integrated into the modeling of the system. This considers public-private partnerships evaluated at different agreement times and promotion of the State for the associative participation of the producers, where simulate the different scenarios allows us to find the elements to be considered as guidelines to formulate public policies.

Finally, the third chapter focuses on the scenario with the best performance obtained and is addressed through sensitivity analysis on policy levers, that is, on those elements that the decision maker can intervene to reinforce the feedback loops and to encourage the performance measures analysed.

This is how the complexity of the system is addressed, analysing a possible strategy to develop collaborative distribution centers through public-private partnerships that stimulate the sector. This gives more power of actuation and decision making to the producer. The understanding of the system through the obtained results will allow us to identify basic guidelines to consider in the definition of public policies that impact the performance of the sector.

Research question

How could the implementation of public policies aimed at strengthening collaborative horizontal logistical relations have an impact on the rural development of Colombian agriculture, as in the case of the potato production sector?

Dynamic hypothesis

The implementation of public policies for strengthening collaborative logistical relations, improves the rural development of Colombian agriculture, according to the analysis of the productive sector of the potato.

General Objective

Understand the possible impacts that the implementation of public policies for strengthening collaborative horizontal logistical relations may have on perform of Colombian agriculture, in the case of the potato production sector, measured through production costs, crop yield and gross financial margin obtained by the producer.

Specific Objectives

- Model the behavior of the potato agricultural sector, considering the post-conflict and climate change conditions.

- Simulate public policy scenarios that impel collaborative relationships in distribution centers that affect rural development in the sector studied.
- Contrast the results of the sensitivity analysis on the policy levers that allow a guideline to improve the performance of the proposed system.

Chapter 1: Dynamic performance of the agricultural sector under conditions of climate change and armed post-conflict

Abstract. The agricultural sector is a strategic source to sustain the population worldwide, however, given the lack of a favourable environment that guarantees its sustainability and growth, this sector is exposed to multiple conflicts and needs, which affect its performance and even causing desertion of the producer. In this research, we model and analyse the agricultural sector of the potato in the Colombian context, which as well as being a strategic food to respond to food crisis, represents the needs of the agricultural sector, where about 90% of producers are classified as small because of their low participation in land tenure and where, in addition to the low-level of technology, the situation of armed conflict and climate change which negatively impacts their results. This paper deals with simulate the agricultural sector of the potato, projecting its results for the post-armed conflict where an improvement in its performance is expected, however it is contrasted with the conditions of climate change to find the real impact in the sector. Since earlier studies address the problem separately, here we propose a dynamic and comprehensive analysis with scope on the production, the intermediation for the marketing of the product and its financial performance, which allows us to understand the real impact on the performance of the sector.

Keywords: Agricultural sector of the potato, dynamic performance management, climate change, post conflict, system dynamics

1 Introduction

According to the Food and Agriculture Organization FAO [1], the world needs to produce at least 50% more food for 9 billion people estimated for the year 2050, considering aspects such as climate change that can affect crop yields up to 25% [2], and increase the volatility of prices that can lead to higher rates of poverty, malnutrition and school dropout, among other factors, and given the background of the agricultural sector in Colombia, the world food safety concern is relevant.

The rural area in Colombia represents 94% of extend the national territory [3], where about 24% of the population lives, being the scenario of multiple problems that affect the country, such as the armed conflict of more than five decades, the presence of illicit crops and social inequality; proof of this is that 0.4% of the agricultural producer units own 41.1% of the total rural area registered by the National Administrative Department of Statistics DANE [3], that is, it is the property or responsibility of a single natural or legal producer. The concentration of land, leads to inequality factors, where for Colombia in the rural area, 41.4% of the population lives in poverty and 18% in extreme poverty [4].

These factors deteriorate with the unproductive, where about 36 million hectares are dedicated to livestock production and could have agricultural or forestry use, generating speculation in prices and a greater concentration of land and wealth. In Colombia, of the total rural area, only 6.3% is destined to crops, that is, about 7.12 million hectares have agricultural vocation (compared to 113 million total rural hectares), and whose production meets the food needs about 70% of the total Colombian population [5], mostly from small and medium-sized farmers.

Additionally, climate change generates direct impacts on crops and plants, given its incidence on rainfall and temperature, aspects that are not unrelated to potato cultivation, which can generally reduce yields on cultivated areas as result of the rise in temperature, thermal and water stress, shorter growth seasons and the presence of pests, among other aspects.

The FAO and the Colombian Ministry of Agriculture through the Institute of Hydrology, Meteorology and Environmental Studies IDEAM [6], using the AquaCrop model, have simulated the productivity of the potato crop under the scenario of variability and climate change in the areas of Cundinamarca and Boyacá, based on the Special Report on Emissions Scenarios (SRES) prepared by the Intergovernmental Panel on Climate Change (IPCC), projecting a decrease in the yield of tuberous production, which oscillates between -2% up to -50%, varying in each semester and according to the place.

The yields in crops, particularly potatoes, have been the subject of research, seeking to counteract the difficulties generated by climate change, studying levels of irrigation, soil type and territorial effects, such as Woli and Hoogenboom [7],. Adabi and Moradi [8],. Dua and Sharma [9], Raymundo and Asseng [10], Deguchi and Iwama [11], Kleinwechter and Gastelo [12].

For its part, the Colombian National Planning Department DNP [13], indicates that after the signing of the peace treaty and as a result of the post-conflict, Colombia may perceive significant results in the economic dividends, due to the extrapolation of the analysis carried out over 36 countries that have ended their armed conflicts, of which 18 are similar to the Colombian case. Among other benefits, the per capita GDP growth is estimated at 71%, the investment rate would go from 29% to 35%, higher foreign investment up to 176%, and an increase of up to 75% in exports.

Several authors address the sectorial impact and quantify the benefits after the post-conflict, such as Santa Maria, Rojas and Hernández [14], Álvarez and Rettberg [15] , Ibañez and Velásquez [16] Authors such as Hewitt and Gantiva [17], Bell and Méndez [18] and Llosa and Casas [19] study the repercussions of the armed conflict on the mental health of the population and its possible effects during the post-conflict.

Several studies have been carried out separately in terms of climatic change and armed post-conflict, and it is in the interest of this work first to analyse the predicted effects together, cents on the one hand it is stated that climate change decreases the yield of crops and in turn the post-conflict generates benefits in the productivity of the sector, and second to integrally simulate the dynamic performance of the sector through a multidimensional measurement that covers the incidence on variables such as crop yield, costs, tons harvested, the sale price among others.

2 Dynamic Performance Management

Dynamic performance management of resources to do higher returns is a complex task, even more when the decision maker is confronted with scenarios where the dynamic interaction of the elements of a system is intertwined with external and internal factors, generating difficulty to find and predict relationships.

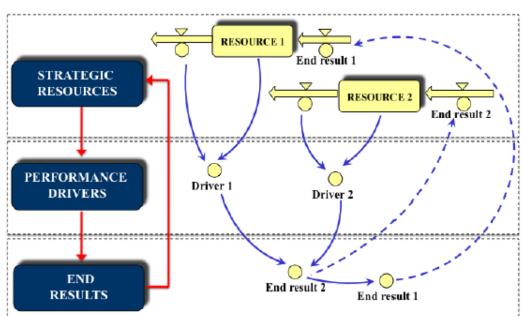


Fig. 1. General structure of Dynamic Performance Management (DPM) [20]

This is how System Dynamics (SD) has been complemented with Dynamic Performance Management (DPM) to support the decision maker in the measurement of performance management and strategy design [20].

Dynamic performance management is approached from three complementary views, an objective, an instrumental, and a subjective [20]. The objective view defines the object of performance management, the instrumental view defines how to affect the object, and the subjective view defines who is responsible for carrying out the activities to do the desired impact. The instrumental vision allows us to understand how allocate of strategic resources affects performance and these in turn influencing the end results [21].

Moreover, the sustainable growth of organizations is analysed through the institutional and inter-institutional levels. This paper studies the agricultural sector of the potato, through the inter-institutional perspective, whose system is composed by producers in different sizes and contributing through the yield of their crop to the supply that is commercialized in the market. The strategic resources are represented in planted areas, harvested tons, product supply, price variation, and financial benefit. These all affect the performance drivers, such as the yield achieved in the crop, the level of intermediation to commercialize the product, the price differences between periods, and the financial gross margin ratio, generating changes in the end results of sowing, harvest, price and financial profit.

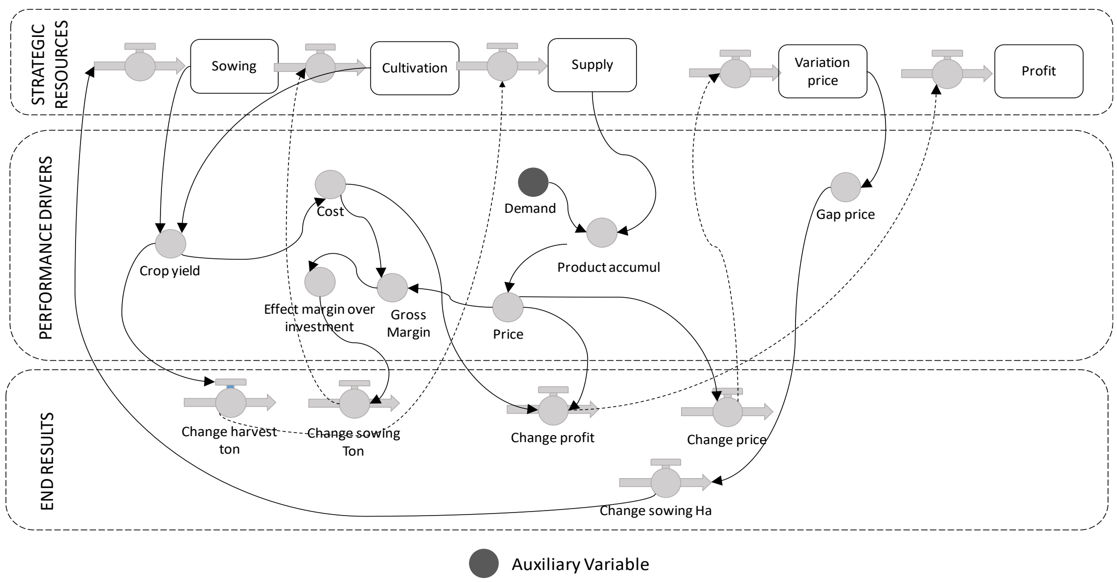


Fig. 2. **DPM of the supply of the agricultural sector of the potato**

Starting from the analysis of the causal relationships, we model the potato agricultural sector taking into account the effect of climatic change, and post-conflict, through three macro processes: production, market and intermediation and financial performance, allowing simulate the system and the valuation of its performance with the multidimensional measurement of the variables of interest, in this case the yield, the cost of production, the financial benefit, the harvested hectares and tons sown, results that in a particular way have an impact on the producers (institutional level), the aggregation to the agricultural sector (inter-institutional level) and therefore customers.

3 Modeling the system

Identified the strategic resources, the performance drivers and the end results, in this session the agricultural sector is modelled, considering the effects of climate change and post-conflict.

3.1 Causal loop diagram

Through causal loop diagrams, the relationships of the system are presented, associated with the loops of financial performance, market and intermediation, and production. These feedbacks influenced by external factors such as climate change and the post-conflict. The feedback loops are presented in the figure 3.

The dynamic behaviour of the system and its effects are analysed through the feedback loops explained below:

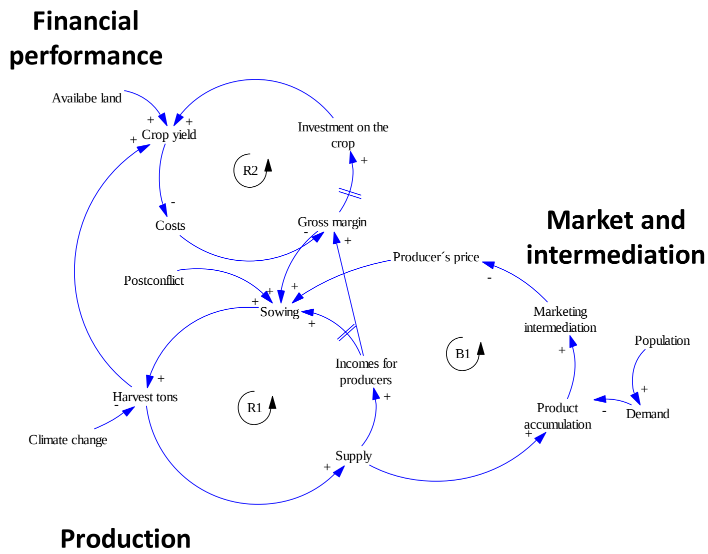


Fig. 3. **Causal diagram of the agricultural sector of the potato**

Production

The reinforcing feedback loop R1 is given by the behaviour of the sowing that allows to get the harvest that will be offered in the market, generating the income of the producer, however added elements such as the post-conflict situation positively encourage the process of sowing due to an environment with more favourable characteristics to develop the rural sector, but in the face of the climate change situation and the high dependence on rainfall on the crop, the tons harvested decrease.

Market and intermediation

Once the harvest is obtained, the product is offered to the market with a natural condition in the sector and is the accumulation of product at certain times of the year, generating an environment encouraging proliferate intermediaries for the retailing of the product, with a direct effect on the price paid to the producer, which ends up affecting the next sowing decision. This is a balancing loop, represented as B1.

Financial performance

The yield of production (tons obtained per hectare sown), impacts the production costs, which in turn determines the economic benefit perceived by the producer and that allows to improve the level of investment on the crop to improve the yield in the next period. The reinforcement loop R2 seeks the increase of the producer's profits with the effect of oscillation due to the delays that occur in the decision-making process and the time required by the crop.

Given the interest of understanding the possible impacts of climate change and the post-conflict on the performance of the potato agricultural sector, the goal is to test the hypothesis defined in subsection 4.4.

3.2 Stock and flow diagram

The stock and flow diagram associated with the feedback loops and the processes described in the dynamic management of performance, is presented in the figure 4.

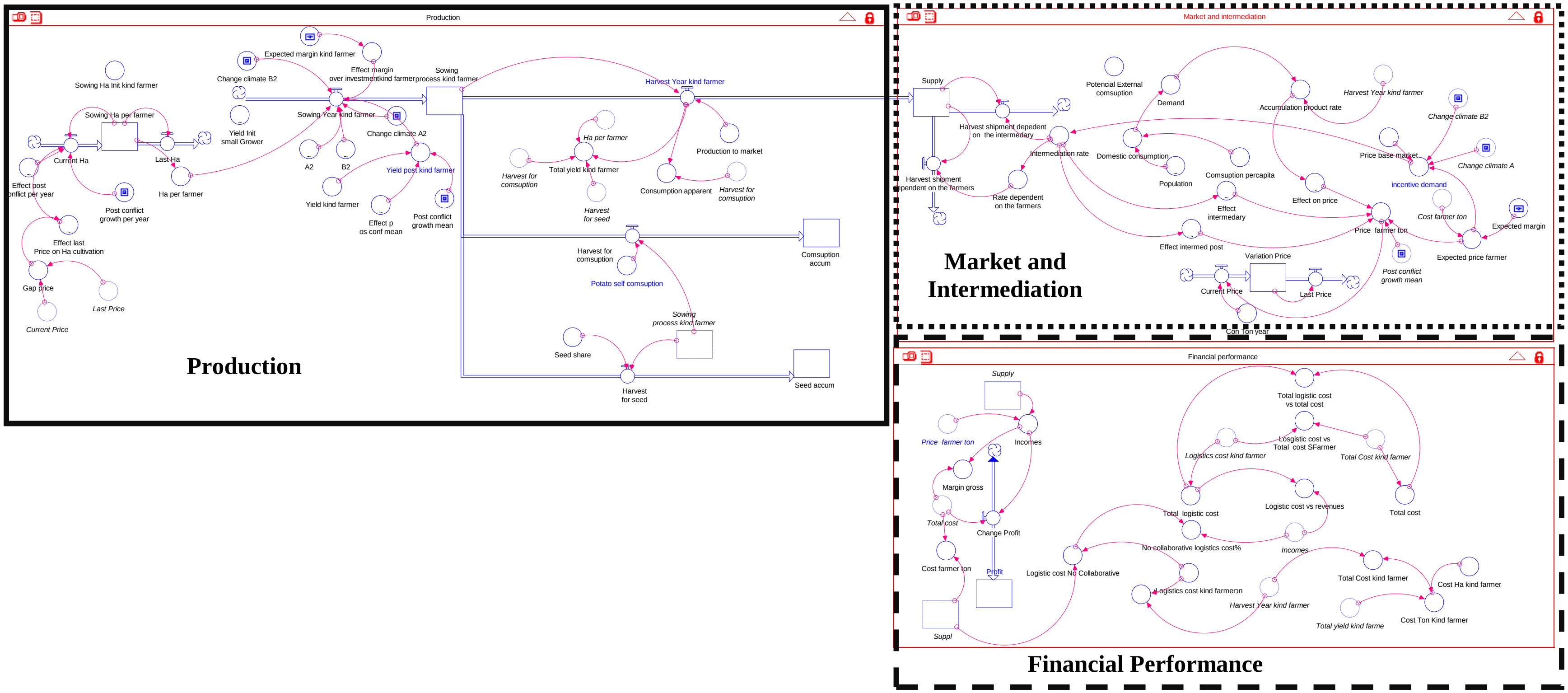


Fig. 4. Stock and flow diagram (summary)

Production

This sector represents the production in different phases of the crop until harvest, according to the type of producer, its size and the performance associated with its characteristics. The type of producer (*i*) is given by its size, where *i*, is 1 = small, 2 = medium and 3 = large. In the stock and flow diagram we observe the variables: cultivated hectares (HS), cultivated tons (TS), and change rates: current cultivated hectares (RHC), cultivated hectares of the earlier period (RLH), rate of cultivated tons (RTS), rate of tons harvested per year (RTH), cultivation rate dedicated as seed (RSS) and rate of cultivation used for self-consumption (RSC). dt is the interval of the solution, the time elapsed between two successive simulation calculations. The equations of the strategic resources in this sector are given by:

- Hectares cultivated by each producer type *i* according to their size:

$$HS_i\ (t) = HS_i(t - dt) + (RHC_i - RLH_i)dt \quad \forall\ i = 1{,}2{,}3 \tag{1}$$

- Tons cultivated by each producer type *i* according to their size:

$$TS_i\ (t) = TS_i\ (t - dt) + (RTS_i - \mathrm{RTH}_i - \mathrm{RSS}_i - \mathrm{RSC}_i)dt \quad \forall i = 1{,}2{,}3 \tag{2}$$

Market and intermediation

This sector represents the relationship between supply and demand which determines accumulate the product in the market, affecting the sale price, which is also sensitive to the level of intermediation and production costs. The stocks are: supply (SP) and price variation (VP) and the change rates are: change of the harvest in the market through intermediaries (RHI), change of harvest in the market through the producer (RHF), current period price (RCP) and earlier period price (RLP). The equations of the strategic resources in this sector are given by:

- Supply of the Product (SP):

$$SP\ (t) = SP(t - dt) + (\textstyle\sum_{i=1}^{n} RTH_i - RHI - RHF)dt \ \text{ where } i = 1{,}2{,}3 \tag{3}$$

- Price Variation (VP):

$$VP\ (t) = VP(t - dt) + (RCP - RLP)dt \tag{4}$$

Financial performance

This sector represents the behaviour of the revenues, general costs, logistics and financial margin resulting from production and demand served, which affects the performance of the next production. the stock variables are total profits and profits by type of producer (PF) and the flow is change in received profits (RPF), and other relevant variables are: cost per ton produced (CTP), total costs (TC), income (IC), gross margin (MG).

The equations of the strategic resources in this sector are given by:

- Total Profit

$$PF\ (t) = PF(t - dt) + (RPF)dt \tag{5}$$

- Profit for each producer type *i* (PF_i):

$$PF_i\ (t) = PF_i(t - dt) + (RPF_i)dt \quad \forall i = 1{,}2{,}3 \tag{6}$$

3.3 Verification and validation of the model

Verification

The logical behaviour of the model is verified through simulate the variables of total cost, total yield, supply, price and sowing. For the case of the cost of the product, an inverse relationship is presented in the figure 5, dependent on the yield of the crop.

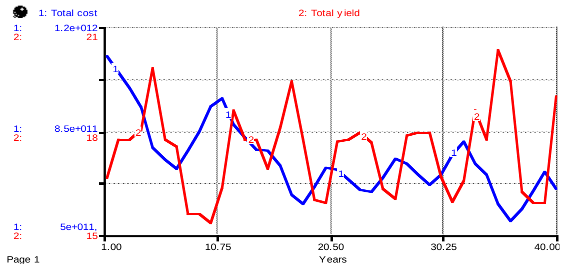


Fig. 5. Verification of the cost and yield of the crop

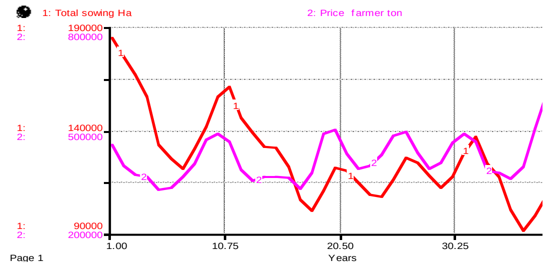


Fig. 6. Verification of the price and sowing

Regarding the sowing process (figure 6), the producer makes decisions based on the price perceived in the previous harvest, presenting a delay associated with the flow of information, to later influence the physical process of cultivated hectares.

Validation

The validation process is carried out through the analysis of mean absolute percentage error (MAPE), comparing the historical data of time series between 17 and 24 years and the data obtained through simulate the dependent variables of the model, such as hectares harvested, tons produced, price and cost, reported by FAO [22].

In the case of hectares planted, the mean absolute percentage error is 14.61%, on the tonnes produced it is 13.52%, on the price and the cost the absolute average percentage error it is 20.14% and 20.33 %, respectively, showing acceptable behaviour that adequately represents the system.

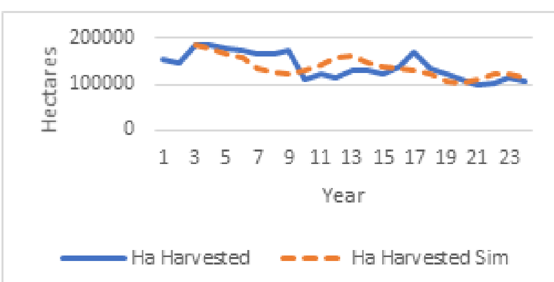


Fig. 7. Validation harvested hectares.

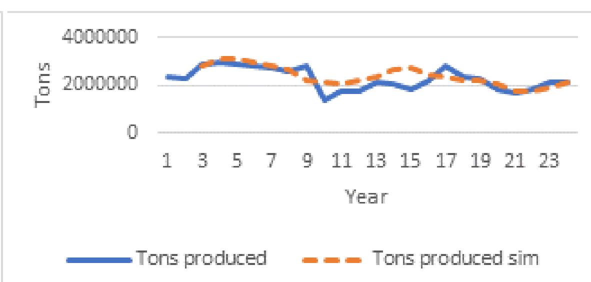


Fig. 8. Validation tons produced

4 Results

The results of the model were analysed through the simulation of scenarios on climate change and post-conflict, to jointly determine how they affect the performance of the sector.

4.1 Climate change scenarios

The possible effects of rainfall on variations in product yields under climate change scenarios are projected by the Food and Agriculture Organization of the United Nations [23], based on these studies, in this research we consider the following scenarios:

Table 1. Climate change scenarios

Scenario	Description
E1	Baseline scenario, without added considerations of climate change
E2	Scenario considering climate change in a very heterogeneous world with continuous increase of the global population; with regionally oriented, fragmented and slow economic growth (according to FAO A2)

4.2 Post-conflict scenarios

According to the National Planning Department (DNP) [13], after the armed conflict experienced by Colombia for about 50 years, and as a result of the peace treaty, a significant improvement in the performance of the national economy is expected, particularly in the performance of the agriculture sector. Based on the above, the following scenarios are considered in the model:

Table 2. Post-conflict scenarios

Scenario	Description
P1	Baseline scenario, without affectation of the post conflict
P2	A scenario that considers the post-conflict based on an analysis of 38 countries that have experienced peace processes and extrapolating these results to the national reality.

Given the interest of studying the performance of the system including the predicted effects by climate change and by the armed post-conflict in Colombia, we start from the premise that the system does not present mechanisms of associativity and collaboration, being producers dependent of the intermediation for commercialization of their products and subject to accumulate production in certain periods due to the effect of climatic precipitations in the absence of technification in the irrigation systems. The simulation considers 18 years, as aggregate planning of the production (yearly), to find the behaviour towards the medium-long term.

4.3 Multidimensional analysis

In order to find the performance of the system and develop the sector, it is analysed from 3 dimensions, cost, yield of the crop and financial margin perceived, with the different combinations of the proposed scenarios.

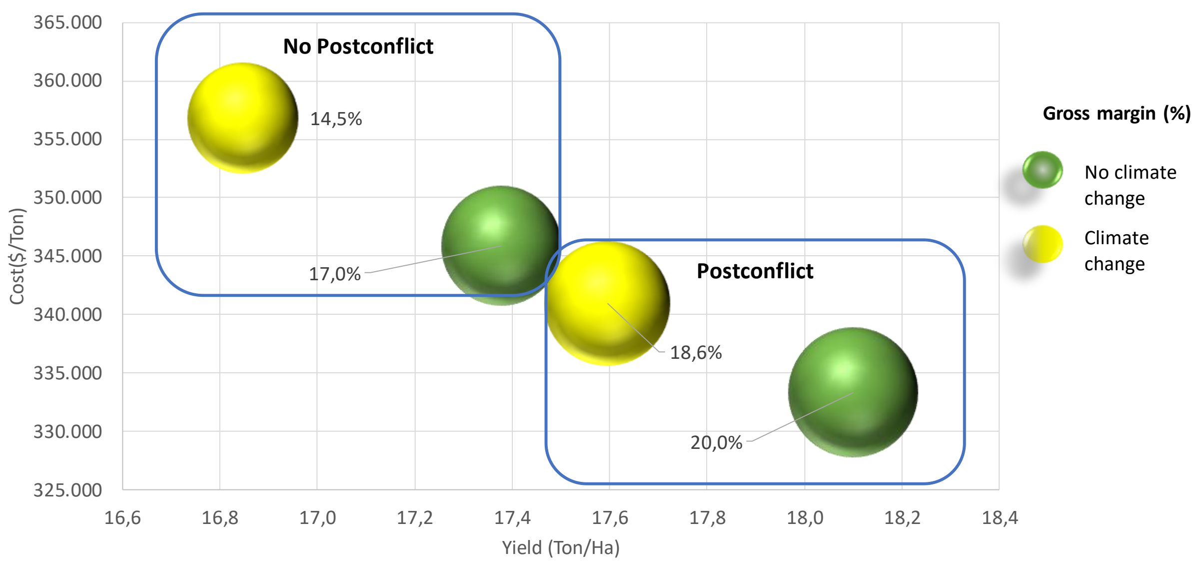


Fig. 9. Multidimensional analysis of the performance of the agricultural sector considering climate change a post-conflict

The highest costs of the product are projected in the scenarios where post-conflict is not considered, with estimated yields between 16.84 and 17.37 tons per hectare planted and with the financial gross margin perceived by the producer decreased in conditions of climate change due to the concentration of the product and decrease in crop yields. When considering the system in post-conflict conditions, the performance measures of cost, yield and gross financial margin improve, however when analyzing the post-conflict scenario with climate change it shows a financial margin of 18.6%, that is, an increase of 1.6% compared to the base scenario (not post-conflict and without changes in climate change), which highlights the need to develop actions that intensify the performance of the sector and its producers to a greater extent.

4.4 Hypothesis testing

To contrast the hypothesis proposed, the statistical software SPSS was used, analysing the results of crop yield, cost per tonne produced and gross financial margin with the model applied for evaluate the effect of climate change and post conflict armed in the agricultural sector, particularly the potato. Null hypothesis or the alternative hypothesis are shown below, where upper indices show the output variables: 1=tons produced, 2=product cost, 3=financial profitability:

Contrast hypothesis

H_0 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does not allow a significant improvement in the performance of the tons produced^1, the cost performance of the product^2 and the performance of the financial rewards perceived by the producer^3.

H_1 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does allow a significant improvement in the performance of the tons produced, the cost performance of the product and the performance of the financial rewards perceived by the producer.

- With a significance level $\alpha = 0.05$ $F \sim F_{0,05;1;78} = 3{,}96 > F_c = 1.02^1$
- With a significance level $\alpha = 0.05$ $F \sim F_{0,05;1;78} = 3{,}96 > F_c = 0.293^2$
- With a significance level $\alpha = 0.05$ $F \sim F_{0,05;1;78} = 3{,}96 > F_c = 2.53^3$
- Decision: To accept the null hypothesis.

Conclusion: The expected positive effect of the post-conflict in the agricultural sector of the potato is counteracted by climate change, without a significant improvement over the yields produced, in the cost performance of the product and in the performance of the financial rewards perceived by the producer.

Conclusions

The agricultural sector in Colombia must face a new panorama, which encompasses social, economic and environmental factors, with great potential at the level of its own development and contribution to resolve global problems, such as food shortages. Potatoes are one of the most widely consumed foods in the world and easily accessible to the poorest, being a key product to meet the increasingly growing food needs, where the agricultural producer is the central axis to do this purpose, however, the reality of the sector shows a great dispersion in the favourable conditions for the farmer, where the small-sized producer predominates, sensitive to both market and environmental variations, given the low-level of investment and technification constraining sustainable growth.

Among the multiple factors that surround the potato sector, the effects of climate change and the condition of armed post-conflict are analysed simultaneously, with the expectation of opposite behaviours, where climate change threatens to reduce the yield of the crop, and after the armed post-conflict a growth of the sector is projected, as a consequence of a lesser desertion of the field, greater investment, better social conditions and a greater presence of the state. When analysing the conjugation of these factors and after the multidimensional evaluation of the performance of the producers and the sector, it is observed that the actions that are unleashed at the level of the armed post-conflict represent an important contribution on develop the sector, however it is counteracted by the effect of climate change, indicating that for a true boom in the sector, strategies with specific focus should be developed, obeying a central development plan.

The multidimensional analysis reveals the most adverse situation for the sector, which is presented under a scenario of armed conflict and with climatic change, with a fall in crop yield of 0.6 tons per cultivated hectare, a decrease of 14.6% on the gross financial margin, a growth of 2.1% of the hectares planted as a result of the low yield of the crop and an increase in the cost per ton of 3.17%, which impacts the consumer price. The best performance scenario is presented as a post-conflict armed situation without climate change, with an increase of 3 percentage points of the financial gross margin, a greater yield of 0.8 tons per hectare planted, a 6.5% decrease in cost per ton, plus conservation of cultivated hectares

When analysing the scenario with the highest probability of occurrence, presence of climatic change and armed post-conflict conditions, it shows a slight rebound in the variables of interest, 1.2% increase in crop yield, a 1.4% decrease in the cost per ton, an increase of 1.3 percentage points in the gross financial margin, plus stability in the hectares planted. Although this scenario shows a better behaviour in contrast to the scenario without climate change and armed conflict, the results show a fairly moderate growth when compared with countries such as China, India and the United States, reaching unfavourable deviations for Colombia. For example, higher product prices between 50% and 65% and lower yield in tons harvested per hectare up to 15%, that is, low performance persists in comparison with other markets, highlighting the need to promote actions of both the public and private sectors, which leverage real development of producers and the sector in general, making it more competitive and with the faculty of addressing challenges of greater globally, even surpassing the national context.

References

1. National Administrative Department of Statistics (DANE), National Agricultural Census 2014, Bogotá (2014).
2. National Administrative Department of Statistics (DANE), Monetary and Multidimensional Poverty: Main results 2014, Bogotá (2015).
3. Agricultural Society of Colombia, Situation and perspectives of agriculture in Colombia, Bogotá (2016).
4. Food and Agriculture Organization of the United Nations: FAO's work on climate change. FAO (2015).

5. International Food Policy Research Institute IFPRI: Climate change, Washington D.C (2009).
6. Food and Agriculture Organization of the United Nations - Ministry of Agriculture: Use of the AquaCrop model to estimate yields for potato cultivation in the departments of Cundinamarca and Boyacá. FAO, Bogotá (2013).
7. Woli P., Hoogenboom, G.: Simulating weather effects on potato yield, nitrate leaching, and profit margin in the US Pacific Northwest. Agricultural Water Management, vol. 201, pp. 177-187 (2018).
8. Adavi Z., Moradi R., Tadayon M., Mansouri H.: Assessment of potato response to climate change and adaptation strategies. Scientia Horticulturae, vol. 228, pp. 91-102 (2018).
9. Dua V., Sharma J.: Forecasting impact of climate change on potato productivity in west Bengal and adaptation strategies. Indian Journal of Horticulture, vol. 74 (4), pp. 533-540 (2017).
10. Raymundo R., Asseng S., Kleinwechter U., Concha J., Condori B., Bowen W., Wolf J., Olesen J., Dong Q., Zotarelli L., Gastelo M., Alva A., Travasso M., Quiroz R., Arora V., Graham W., Porter C.: Performance of the SUBSTOR-potato model across contrasting growing conditions. Field Crops Research, vol. 202, pp. 57-76 (2017).
11. Deguchi T., Iwama K., Haverkort A.: Actual and potential yield levels of potato in different production systems of Japan. Potato research, vol. 59 (3), pp. 207-225 (2016).
12. Kleinwechter U., Gastelo M., Ritchie J., Nelson G., Asseng S.: Simulating cultivar variations in potato yields for contrasting environments. Agricultural Systems, vol. 145, pp. 51-63 (2016).
13. National Planning Department (DPN): Economic dividend for peace, Bogotá, (2015).
14. Santa Maria M., Rojas N., Hernández G., Economic growth and armed conflict in Colombia, Bogotá (2013).
15. Alvárez S., Rettberg A.: Quantifying the economic effects of conflict: An exploration of the costs and the studies on the costs of the colombian armed conflict. Colombia Internacional 67, pp. 14-37 (2008).
16. Ibáñez A., Velásquez A.: The impact of forced displacement in Colombia: socio-economic conditions of the displaced population, linkage to labor markets and public policies. CEPAL, Series social policies, Santiago de Chile (2008).
17. Hewitt N., Gantiva C., Vera A., Cuervo M. , Hernández N., Juarez F., Parada A.: Psychological effects on children and adolescents exposed to armed conflict in a rural area of Colombia. Acta Colombiana de Psicología, vol. 17, pp. 79-89 (2014).
18. Bell V., Méndez F., Martínez C., Palma P., Bosch M.: Characteristics of the colombian armed conflict and the mental health of civilians living in active conflict zones. Conflict and Health, vol. 6 (1), pp. 1-8 (2012).
19. Llosa A., Casas G., Thomas H., Mairal A., Grais R, Moro M.: Short and longer-term psychological consequences of operation cast lead: documentation from a mental health program in the Gaza Strip. Conflict and Health, vol. 6 (1), pp. 1-10 (2012).
20. Bianchi C.:Enhancing performance management and sustainable organizational growth through System-Dynamics Modeling. In Systemic Management for Intelligent Organizations: Concepts, Models-Based Approaches and Applications. Springer Berlin Heidelberg. inbook, pp. 143-161 (2012).
21. Cosenz F.: Supporting start-up business model design through system dynamics modeling. Managemente decision, vol. 55 (1), pp. 57-80 (2017)
22. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17.
23. Food and Agriculture Organization of the United Nations (FAO): Use of the AquaCrop model to estimate agricultural yields in Colombia. FAO, Bogotá D.C. (2013).

Chapter 2: Modeling collaborative logistics policies that impact the performance of the agricultural sector

Abstract. The performance of the agricultural sector is considered a fundamental factor for achieving sustainability of the most vulnerable population as well to meet the world's food needs. This is how countries like Colombia recognize in their government plans the importance of the development of sector leveraged by infrastructures boosting their results; however, the instrumentation and design of public policies are a challenge for the governors given the dynamic complexity of the system. Through this research, we propose a model for the analysis of logistic public policies in the agricultural sector of the potato, where the collaboration through public-private partnerships (PPP) for the implementation of distribution centers act as an integrating axis among the producers, allowing the multidimensional measurement of its dynamic performance through simulating production, intermediation for its commercialization and financial results.

Keywords: Public policies, collaborative logistics, agricultural sector, dynamic performance management, system dynamics.

1 Introduction

Nearly 46% of humanity is located in rural areas [1], whose main activity is related to the agricultural sector, boosting the economy of developing countries and considered as a primary source for feeding the undernourished population, especially in those areas. Around the world, 37.7% of the total land is for agricultural activities, however, aspects such as climate change, degradation of natural resources and factors of violence, among others, affect farming capacity, risking the livelihood of 70% of the poor who live in rural areas and whose main source of income depends on the agricultural activity, plus also risking their ability to respond to the nutritional needs of the urban population.

These characteristics and their constant change must lead to the transformation and special attention of the value chains with higher efficiency demands, in a sector dominated by the variability of the farmer's conditions, the inequity in land tenure and limited access to efficient infrastructure, which allows improving the conditions of the population and its competitiveness.

In this way, from the logistics networks point of view, the challenge arises first, balancing the variability of the conditions of supply and demand, second reducing the uncertainty in decision-making in a sector that requires both technical support to improve crop yields, and third implementing best practices for the conservation, storage and disposal of products that are mostly perishable, as is the case of potatoes, a key point of reference in this research and considered a fundamental product as an ancestral and cultural exponent of South America and that has served as a food base for the most vulnerable population in the world, given its nutritional and accessibility characteristics, occupying the fifth place of agricultural products of higher consumption worldwide [2].

The development of the rural sector is intimately related to the development of the agricultural producer, which comprises a set of elements to improve social, economic, and environmental dimensions, as well as technical quality of their production processes. In this research we evaluate performance multidimensional through the production obtained, the costs per ton and the gross margin reached by the producer, among other variables such as the yield of the crop, the prices received and the harvested hectares, the foregoing based on what has been exposed by authors such as Vilches et al [3], Naharro [4], David [5], Dwyer [6]. In the agricultural sector, like other types of supply chains, there are vertical and horizontal relationships, where alliances are considered a fundamental factor for productivity and competitiveness. This is exposed by authors such as Viera and Hartwich [7], Rojas [8] , Kaplinsky [9] y Garza [10].

The approaches in the analysis of agricultural supply chains have a high tendency towards vertical collaboration models, understanding as vertical collaboration those that unite companies or entities in successive phases of the value chain, these are collaboration agreements between suppliers and customers [11]. According to Burgers [12] alliances between competitors are known as horizontal collaboration, where the entities involved operate in adjacent stages of the supply chain, cooperating with each other in processes prior to the natural competition that occurs in the market. Becerra et al [13], present a model that allows to analyse the strategy of horizontal collaboration through a logistics operator, as the central axis of several clients with similar characteristics.

This work has the purpose of analysing the dynamic performance of the agricultural supply of potatoes in Colombia and the incidence of horizontal collaborative processes in distribution centers, which allow the formulation of public policies aimed at improving the performance of the rural sector and given its dynamic behaviour and continuous feedback.

The proposed model is developed using Systems Dynamics, considering the approach of various authors and their research proposals, which are analysed from the perspective of capacity planning in the supply chain, through private public partnerships and the encouragement level of the model by the State.

2 Dynamic performance management

The dynamics of both the public and private sectors are addressed as a constant interaction in search of value creation and sustainable development, which as indicated by Bianchi [14], the identification of relationships contributes to the understanding of the systems, and to its planning and control systems for improving the performance of the actors. Based on the methodology of dynamic performance management (DPM) and its instrumental vision, the causal relationships between the different levels of a system are analysed, considering the strategic resources, drivers of performance and final results, for its later subsequent modeling, verification and validation.

In the case of the agricultural sector of the potato, three subsystems are considered production, market and intermediation, and financial performance, where the strategic resources represent the stocks of the system's fundamental assets, such as sowing, harvesting, the supply and variation of the price received by the producer, and the profits obtained, which are affected by the end results, either as physical or information flows and that are driven by the yield of the crop, the relationship of intermediation for marketing, the accumulation of the product in the market, the variations in the price received and the gross financial margin obtained as a result of the year.

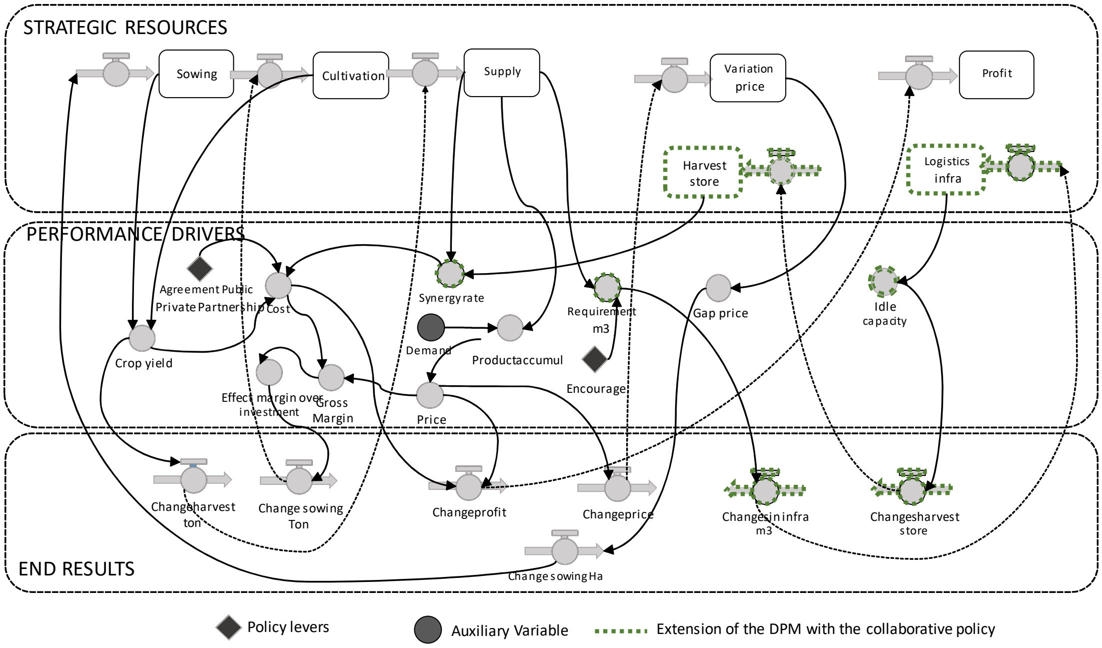


Fig. 1. Dynamic performance management chart of the supply of the agricultural sector of the potato

The integral analysis of these relationships, as well as the understanding of causality between the different factors, facilitates decision-making system intervention, being the outputs of the system the harvest and product supply in the market and being the main outcome the profitability of the producer.

Once the causal relationships among the strategic resources, performance drivers and final results have been understood, to measure the impact of public policies emphasized on collaborative logistics on the performance of the agricultural sector, measured multidimensional as the product costs, tons produced, and financial performance we considered an expansion of the DPM, whose main strategic resource is the infrastructure of specialized distribution centers where producers converge and which allows them to adopt a central role not only as generators of the product, but as direct managers in its commercialization, decreasing the level of intermediation and balancing supply and demand, in the face of climate change conditions and with projections of the Colombian war post-conflict.

3 Modeling the system

In this section we present the modeling of horizontal logistics collaboration strategy through distribution centers, along with the verification and validation of the model.

3.1 Causal loop diagram considering the collaboration strategy

The relationships are analysed through a causal diagram, where the interaction of production is identified with the development of the sector and how it depends on external aspects such as the weather, which can fragment the conditions of the producers and their associativity

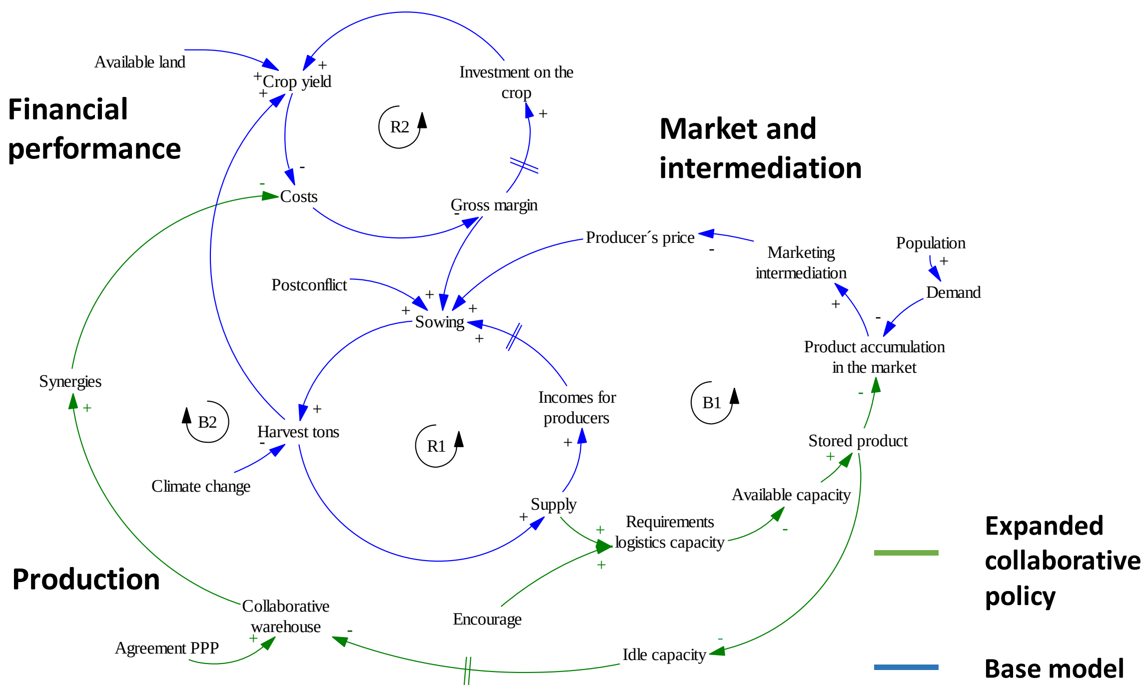


Fig. 2. Causal loop diagram expanded with collaborative policy

The dynamic behaviour of the system and its effects are analysed through the feedback loops as explained below.

Production sector

The process of sowing and the later harvest of the potato, generate the supply of the product in the market, volume that together with the price per ton will be the income of the producer. Likewise, production is affected by the effects of climate change and post-conflict conditions in the Colombian rural sector. The feedback flow of the production is evidenced in the reinforcing loop R1, generating an oscillation effect due to the delay in the decision of the producer to grow hectares according to the last income obtained.

Market and intermediation

Although the supply determines the price of the product in the market, the interaction of collaborative infrastructures allows the supply to be balanced against the demanded product, which generates a competitive advantage for the producer, counter-mediating the marketing of the products in the market, as represented in the balancing feedback loop B1.

Financial performance sector

The production cost partly determines the producer's profits, which in turn contributes to the development and sustainability, being a differential factor for market competitiveness. Likewise, external factors such as climate change and internal factors such as the level of investment on the crop, impact performance, which in turn determines the cost of production and the profitability obtained. The feedback flow is evidenced in the reinforcing loop R2, seeking the increase in crop yield, with and oscillation effect.

Including collaborative policy, synergies and costs

. When considering the strategy of collaboration between producers through distribution centers, the causal relationships are extended. The implementation of a collaborative public policy increases the synergies among the producers, counting on a physical platform that materializes the collaboration and economic benefits for the sector and its producers, represented in the balancing loop B2.

3.2 Stock and flow diagram

The stock and flow diagram for the sectors used in the validation of the behaviour of the model are shown in figure 3, where the production, the market and intermediation and the financial performance of the producers are considered.

Production sector

In the stock and flow diagram we observe the variables: cultivated hectares (HS), cultivated tons (TS), tons used as seed (TSS), cultivation dedicated to self-consumption (SC) and change rates: current cultivated hectares (RHC), cultivated hectares of the earlier period (RLH), rate of cultivated tons (RTS), rate of tons harvested per year (RTH), cultivation rate dedicated as seed (RSS) and rate of cultivation used for self-consumption (RSC). The main equations are given in the following way, where *i* = type of producer by its size, *1 = small, 2 = medium and 3 = large,* according to the amount of hectares sown, defined by the Agrocadenas Observatory of Colombia [15] and the National Administrative Department of Statistics (DANE) [16] .

- Hectares cultivated by each producer type *i* according to their size (HS):

$$\frac{dHS}{dt} = RHC_i - RLH_i \quad \forall\, i = 1{,}2{,}3 \quad (7)$$

- Tons cultivated by each producer type *i* according to their size (TS):

$$\frac{dTS}{dt} = RTS_i - \mathrm{RTH}_i - \mathrm{RSS}_i - \mathrm{RSC}_i \;\forall\; i = 1{,}2{,}3 \;(8)$$

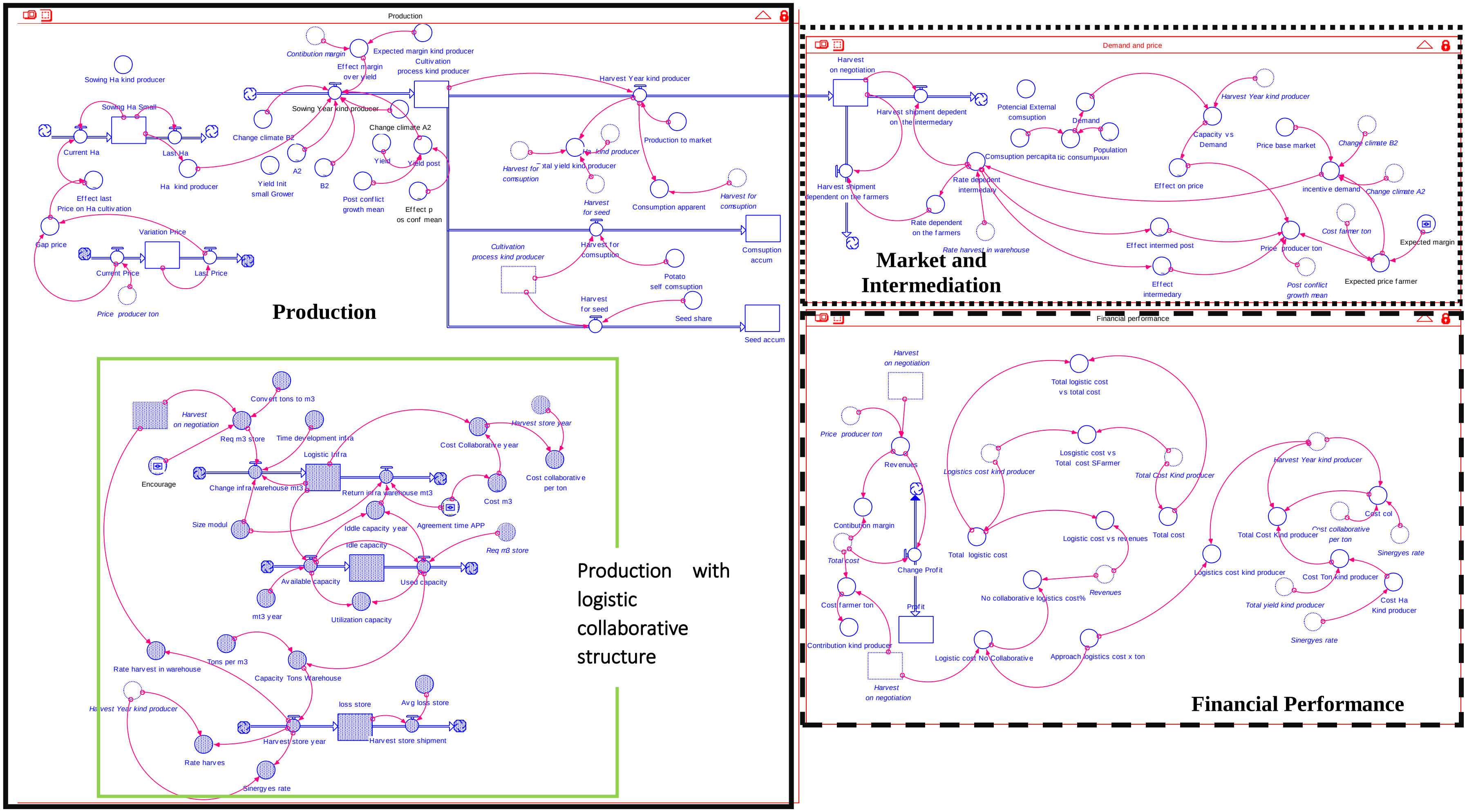


Fig. 3. **Stock and flow diagram including logistic collaborative structure (summary)**

Market and intermediation

In this sector and according to the stock and flow diagram, the stocks are: supply (SP) and price variation (VP) and the change rates are: change of the harvest in the market through intermediaries (RHI), change of harvest in the market through the producer (RHF), current period price (RCP) and earlier period price (RLP). Other significant variables in the sector are dependence on intermediation (DI), producer expectation price (EPP), product accumulation (PA), domestic demand (D), price received by the producer (PPP). The main equations of the sector are given by:

- Supply (SP)

$$\frac{dSP}{dt} = \sum_{i=1}^{n} RTH_i - RHI - RHF \quad \forall\, i = 1,2,3 \qquad (9)$$

- Price variation (VP)

$$\frac{dVP}{dt} = RCP - RLP \quad \forall\, i = 1,2,3 \qquad (10)$$

Financial performance sector

In the financial performance sector, the stock variables are total profits and profits by type of producer (PF) and the flow is change in received profits (RPF), and other relevant variables are: cost per ton produced (CTP), total costs (TC), income (IC), gross margin (MG).

- Total profits (PF):

$$\frac{dPF}{dt} = \mathrm{IC} - \mathrm{TC} \qquad (11)$$

- Profits for each producer type *i* (*PF$_i$*):

$$\frac{dPF_i}{dt} = \mathrm{IC}_i - \mathrm{TC}_i \qquad (12)$$

Extension of the production sector including the logistics collaboration structure.

Given the interest for proposing collaborative policies in distribution centers, which allow the associativity of producers and the implementation of strategies that balance supply and demand, the development of collaborative infrastructures for the storage and distribution of the harvest is considered. The sector considers the available capacity and the development of warehouses, the unused capacity, as well as the associated agricultural production units, among others.

The expansion of the production sector considering include the elements of the collaborative public policy, has the following stock variables: logistic infrastructure (WH), idle capacity (IDC), loss of stored harvest (LS); the flows are: change of new infrastructure (RNWH), return of infrastructure (RRWH) available capacity (RAC), capacity used (RUC), harvest received in the warehouse (RHS), harvest stored and dispatched (RHSS). Other relevant variables in the expansion of the sector are: relationship of synergies (SR), requirement of cubic meters for storage (SMR), capacity use (UC). The main equations are:

- Logistics infrastructure (WH):

$$\frac{dWH}{dt} = RNWH - RRWH \qquad (13)$$

- Idle capacity (IDC):

$$\frac{dIDC}{dt} = RAC - RUC \qquad (14)$$

- Loss of stored harvest (LS):

$$\frac{dLS}{dt} = RHS - RRHS \qquad (15)$$

3.3 Model verification and validation

Model Verification

Through the verification process it is determined if the operational logic of the model corresponds with the logic of the design; for this, the behavior of the cost, the yield of the crop, the price received by the producer, the cultivated hectares and the supply were verified.

The yield of the crop, that is, the amount of tons of product obtained per hectare planted, is closely related to the cost per ton harvested, representing an inverse relationship (figure 4), where the cost variable acts depending on the crop yield. The supply of product has an effect on the price received by the producer, because the accumulation of product, added to the level of intermediation, generates an imbalance with respect to demand, reflected in the growth or decrease in the price per ton (figure 5).

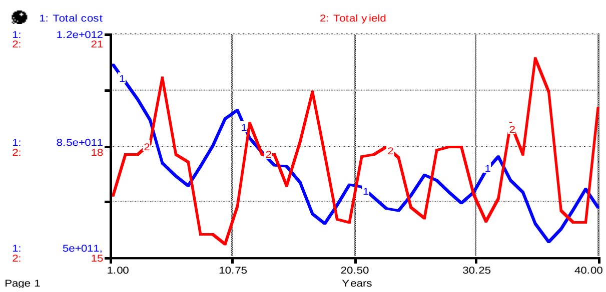


Fig. 4. **Verification of the cost and yield of the crop**

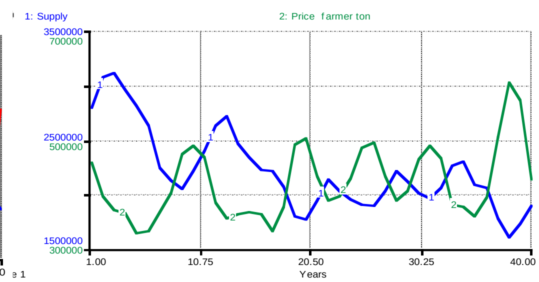


Fig. 5. **Verification of the price and supply**

Model validation

For the validation of the behaviour of the model, the analysis was performed on the variables that depend on the model and that define the behaviour of the system, such as hectares harvested, tons produced, price and cost, using the mean square error between historical data of a time series between 17 and 24 years, according to the historical information reported by FAO [17].

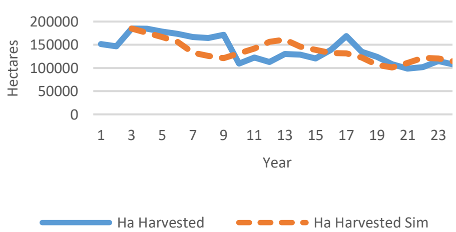


Fig. 6. **Validation of harvested hectares**

Fig. 7. **Price validation**

The absolute average percentage error obtained for the hectares planted was 14.61%, for the harvested tons and the per capita consumption was 13.52%, for the cost of the producer was 20.33%, and for the price of the producer 20.14%, representing acceptable deviations from the real behaviour versus the simulated

4 Results

Given the interest of studying the performance of the system after the inclusion of collaborative logistics policies, where the distribution centers act as a central axis for the collection, storage and distribution of the product, balancing the demand and supply and impacting the level of intermediation commercial for the achievement of better results, measured in cost, crop yield and financial gross margin perceived by the producer, the evaluated strategies combine the implementation of public-private partnership for the administration and operation of the distribution centers and the encouragement level of the model by the State:

Table 1. Strategies for the evaluation of the performance of the system

	Strategy			
Strategic elements	**1 (S1)**	**2 (S2)**	**3 (S3)**	**4 (S4)**
Public-private partnership <15 years	X		X	
Public-private partnership >15 years		X		X
Encouragement non-segmented participation >50% population	X	X		
Encouragement with segmented participation <50% population			X	X

The strategies are contrasted with the results obtained without implementing the collaborative logistics policy, represented as "E2P2 (No Policy)", but which considers the post-conflict situation and climate change, obeying the probable conditions that the system will face.

4.1 Multidimensional analysis

The best performance of the system is observed in the multidimensional analysis, where the S4 strategy represents a private public alliance greater than 15 years and a moderate promotion of the collaborative model of the State towards the producer, that is to say that it congregates less than 50% of the total production, generating the lowest cost per ton produced ($315,713/ton), the highest yield (18.2ton/ha) and the highest gross financial margin (24.8%).

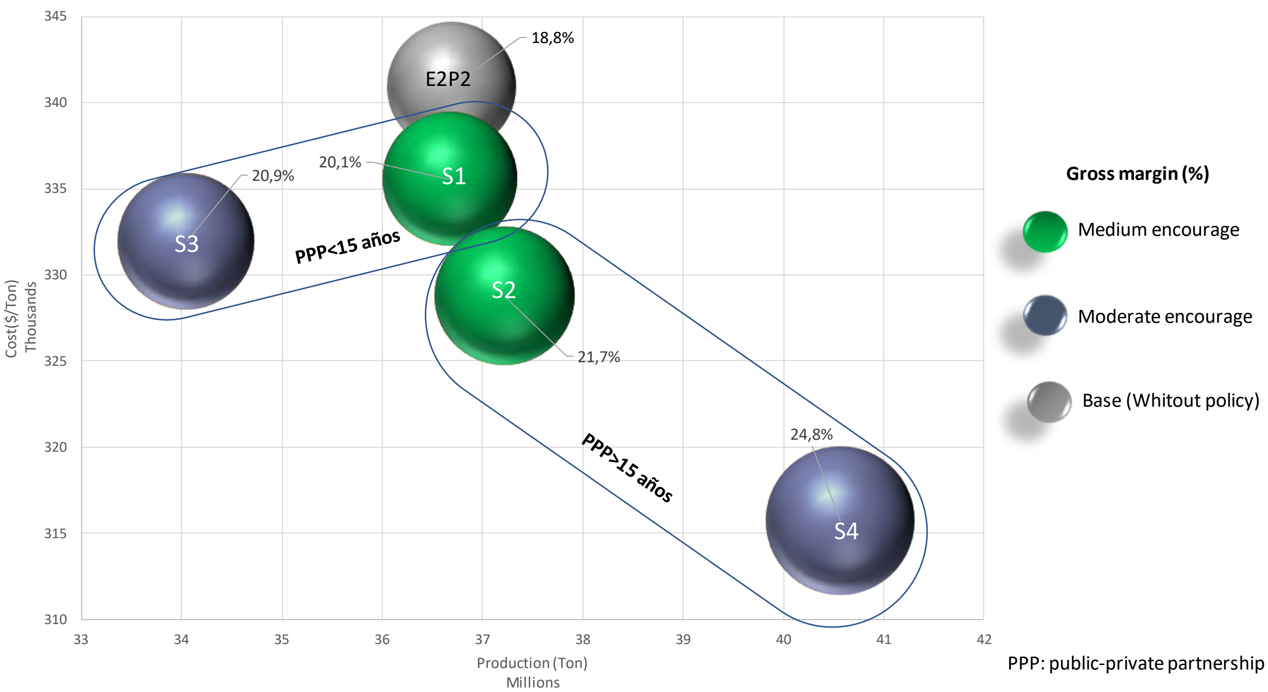


Fig. 8. Multidimensional analysis including the collaborative policy

Likewise, S4 strategy compared to the base scenario without policy inclusion (E2P2), shows a better performance in the system. The behavior of the different scenarios are contrasted through the strategic resources and performance drivers defined in the system as shown in figures 9 and 10, showing the sensitivity of the model to decision-making and where the financial profit as a result of the exercise presents the best performance under the S4 strategy.

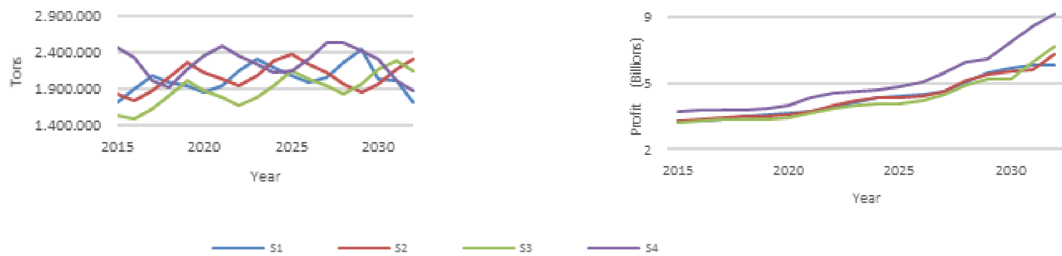


Fig. 9. Behaviour of strategic resources: cultivation and profit under four different strategies

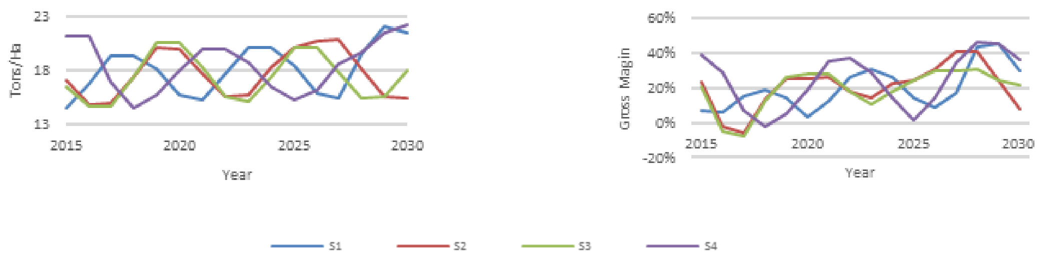


Fig. 10. Behaviour of performance drivers: yield and gross margin under four different strategies

On the other hand, S2 strategy (public-private partnership greater than 15 years and medium encouragement of the collaborative model from the State towards the producer) represents in its greatest the second best projected performance, however, given the need to increase the development of the logistics infrastructure, it increases the risk of idle capacity, generating greater pressure on the system to increase its use, hence the importance of state intervention to accelerate the sustainable participation of producers under the collaborative model.

4.2 Hypothesis testing

To make the contrast of the hypothesis, the statistical software SPSS was used, analysing the results of crop yield, cost per tonne produced and gross financial margin with the model applied for the evaluation of public policy of collaborative logistics in the agricultural sector, particularly the potato, through distribution centers. This analysis was carried out using a multivariate general linear model: The null hypothesis and the alternative hypothesis are shown below, where upper indices show the output variables: 1=tons produced, 2=product cost, 3=financial profitability:

H_0 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, does not influence the amount of tons produced^{1}, the cost of the product^{2} and the financial profitability perceived by the producer^{3}.

H_1 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, influences the amount of tons produced, the cost of the product and the financial profitability perceived by the producer.

- With a level of significance α de 0.05 $F \sim F_{0{,}05;1;78} = 3{,}96 < F_c = 13{,}67^{1}$,

- With a level of significance α de 0.05 $F \sim F_{0,05;1;78} = 3,96 < F_c = 7,92$[2],
- With a level of significance α de 0.05 $F \sim F_{0,05;1;78} = 3,96 < F_c = 7,96$[3]
- **Decision:** Reject the null hypothesis.
- **Conclusion:** The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, influences the amount of tons produced[1], the cost of the product[2] and the financial profitability perceived by the producer[3].

Conclusion

In this article the impact of horizontal logistics collaboration through distribution centers in the potato agricultural sector has been evaluated, which allows for the evaluation of public policy instruments and to improve their performance, the above using a multidimensional analysis of the variables associated with production, market, intermediation, and financial performance.

Public policy starts from the premise of the development of public private alliances, where the time agreed between the parties affects the performance of the sector and, according to the modeling, better results are obtained when public private alliances exceed 15 years, given the stability that exists, positively impacting the costs per ton. On the one hand, the encouragement from the State towards the producer affects the level of commitment and interest of this actor, and where a moderate level of encouragement leads to the best results, this for a sustainable coverage of the infrastructure of the collaborative warehouses and their permanent occupation. For the case of this work, it supposes a moderate level of encouragement of the model reaching up to 50% of the productive population, which despite being counterintuitive, is accepted by the times required for the implementation of infrastructures, the sensitivity of idle capacity over financial performance and the uncertainty of crop yield associated with climate change, showing the need to open several distribution centers that gather, through an adequate logistics network, the productive, geographic and product distribution requirements, acting as decentralized physical nodes.

With the approach of the horizontal logistics collaboration between producers through the distribution centers, the financial margins are improved reaching an increase between 6 and 9 points, as the need for intermediation decreases and a better balance between supply and demand is achieved, where the synergies achieved allow economies of scale that favour the level of investment on the crop to obtain higher yields in the harvest.

The number of tons harvested show a growth of up to 11% during the simulation time (15 years), after the analysis with the assumption of implementation of the collaborative public policy, which is associated with a higher crop yield, where it would go from generating in average 17.6 tons/hectare to 18.2 tons/hectare, as a result of the higher profitability perceived by the producer that allows a better investment on the crop, as well as a more equitable price to offset the level of intermediation for its marketing, encouraging the decision of cultivation.

Production costs are positively impacted despite the generation of new costs related to the collaborative logistics of the distribution center, since the simulation does not suppose a subsidized model, that is, the producer must pay the access to the specialized infrastructure, compensated by the synergies achieved and whose benefits are mainly due to the balance reached between supply and demand, a decisive position for the management of prices and the commercialization of the product. The cost presents a decrease of up to 15.6%, allowing the producer a greater development and enabling it strategically for its growth and access to new markets, in a sustainable and profitable manner.

It is not possible to talk about rural development, without thinking about the development of the agricultural producer, therefore the actions generated for the intervention of the sector should be strategically focused on its competitiveness, guaranteeing the sustained rise of its economic, social and environmental realities , hence this work starts from the characterization of the producer and its performance over time, showing that collaborative relationships foster their development and therefore the associated environment, through a system based on productivity, to achieve greater competition that enhance access to new markets and not a protectionist system that limits the development of the sector.

References

1. World Bank, Homepage, http://data.worldbank.org/topic/agriculture-and-rural-development, last accessed 2016/05/05.
2. Food and Agriculture Organization of the United Nations: Statistical Pocketbook: World food and agriculture. FAO, Rome (2015).
3. Vilches, A., Gil D., Toscano J., Macías, O.: Rural development and sustainability (2014), http://www.oei.es/decada/accion.php?accion=22, last accessed, 2018/03/21.
4. Naharro, M.: Rural development and sustainable development. The ethical sustainability. Ciriec, Public, Social and Cooperative Economy Journal (55), 7-42 (2006)
5. David, M.: Rural development in Latin America and the Caribbean: the construction of a new model?. CEPAL-Alfaomega, Bogotá (2001).
6. Dwyer, J.: Review of rural development instrument. University of Gloucestershire, London (2008).
7. Viera, L., Hartwich F.: Approaching puiblic-private partnership for agroindustrial research: A methodological framework. San José, Costa Rica (2002).
8. Rojas, M.: Productive alliances as an instrument of rural development in Colombia. In: Policies, instruments and experiences of rural development in Latin America and Europe. Ministry of Agriculture, Fisheries and Food of Spain, Madrid (2002).
9. Kaplinsky, R.: Spreading the gains from globalization: What can be learned from value chain analysis?. Problems of Economic Transition 47(2), 74-115 (2014).
10. Garza, F.: Public-private partnerships for research and development in agroindustrial chains: The situation in El Salvador. ISNAR, San José (2003).
11. Ariño, A.: Strategic alliances: Options for the growth of the company. In: Financial strategy, vol 236, pp. 40-51 (2007).
12. Burgers, W., Hill, C., Kim, C.: A theory of global strategic alliance: The case of the global auto industry. Strategic management journal 14(6), 419-432 (1993).
13. Becerra, M., González, C., Herrera, M., Romero, O.: Collaborative planning capacities in distribution centers. In: Theory, methodology, tools and applications for modeling and simulation of complex systems: 16th Asia Simulation Conference and SCS Autumn Simulation Multi-Conference, AsiaSim/SCS AutumnSim, Proceedings, Part I, pp. 622-632, Beijing, China (2016).
14. Bianchi, C., Dynamic Performance Management. Springer International Publishing, Switzerland (2016)
15. Agrocadenas Observatory Colombia: The potato chain in Colombia, Bogotá (2005).
16. National Administrative Department of Statistics (DANE): National Agricultural Census 2014, Bogotá (2014).
17. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17.

.

Chapter 3: Guidelines for collaborative public policy in the agricultural sector based on the analysis of dynamic sensitivity

Abstract. The agricultural sector is considered strategic to overcome the growing food demand in the world and promote the sustainability of nations, as is the case in Colombia. The importance of defining public policies as guidelines that promote sustainable development and collective well-being generates special interest in the adequate definitions that constitute the policy. This research presents a dynamic sensitivity analysis of the levers of collaborative public policy, addressing parameters that promote the performance of the system and potentiate its dynamics measured multidimensional as costs, production, and the financial gross margin. We propose a system dynamics model that considers the horizontal logistic collaboration between producers and simulates public-private relations for the implementation of distribution centers in the agricultural sector of the potato in Colombia.

Keywords: Agricultural sector of the potato, public policy, policy levers, public-private partnership, horizontal collaborative logistics, system dynamics

1 Introduction

Colombia with a population of more than 48 million people and with an area of around 1.1 million km^2 [1] is the fifth largest country in Latin America. Colombia has great geographical benefits such as direct access to the Pacific and Atlantic oceans as well as a variety of climatic zones, abundance of natural resources, and an extensive biodiversity.

It is within these settings that the agricultural sector has developed great wealth in terms of variety with only moderate importance in the economic performance of the country. According to data from the World Bank [2], Colombia´s agro sector reached a share in the national GDP of 6.45% in 2017. This has decreased compared to earlier years for example; in the year 1990 the participation was 16.2%. This demonstrates the challenges of the agricultural sector particularly a scenario of multiple problems such as; armed conflict, low technification of producers, climate change conditions, and displacement of its inhabitants and the proliferation of illicit crops, among others.

The national government has historically highlighted the importance of promoting the agricultural sector. Proof is the national development plans of the last twelve years [3], [4], [5]. These plans are recognized in the agricultural sector as a strategic axis for the sustainable growth of the country covering issues such as innovation, eradication of illicit crops, reduction of production costs, land restitution and reparation to the victims of the armed conflict and in its analysis. Those national development plans coincide with the deficiencies in productivity that the sector has gone through, which added to the inefficient infrastructure diminishes competition and the opportunity to generate robust value chains.

To promote the agricultural sector as a driver of economic growth and international integration it is necessary, as the OECD [6] points out, to take on challenges at a structural and institutional level. This is accomplished through policies that enhance its competitiveness in the long-term and whose challenges range from the development of infrastructures, land tenure systems, information systems, education, research, ordering and institutional coordination, among others.

Aligned with these challenges, the national development plan 2014-2018 [5] frames the challenge of infrastructure as a trigger of the development of the countryside. This encourages the reduction of costs and improvement of the conservation of products along the logistics chain. The deficiency and quality of infrastructure has generated the appearance of many of intermediaries in the supply network, weakening the position of the producers.

On the other hand, there's a generally low level of associativity of Colombian agricultural producers. According to the national agricultural census of 2014 [7] shows how 73.7% of producers declare that they do not belong to any association or union. This reduces the possibility of access to more and better practices that raise their conditions and enhance their competitiveness and positioning in the logistics network. This is done through greater synergies, cost impacts, opportunity and innovation, among other aspects. That is; a greater capacity of the process to attend increasingly dynamic markets with variable demands and globalized supply chains.

The integration of agricultural logistics processes depends directly on the aggregate planning of supply chain requirements. It is there that distribution centers are recognized as central nodes of the network directly influencing planning and development of other logistic activities. Such as; the supply of materials, in-store administration, final assembly of the product, value-added processes and planning for the distribution of the merchandise. In a world that constantly seeks models just in time, with greater speed and less waste; the distribution center plays a key role as it is the place where one wants to balance supply and demand.

On the collaborative processes for the management of the supply chain, vertical tendencies are highlighted. Simatupang [8] presents the collaboration as the agreements between retailers and suppliers based on the incorporation of change of information, timing of decisions, and alignment of incentives. Stefasson [9] defines the actors in a collaborative network, including logistics service providers as the central axis between suppliers, products, and consumers. Mentzer and Kennet [10] define the processes CPFR (Collaborative Planning Forestry and Replenishment) as a fundamental pillar for business partners to reach an agreement on the goals of the alliance, the development of joint sales, operational plans and collectively generate and update projections. That is; vertical collaboration occurs between complementary actors in the logistics network from the provider to the consumer. However, the horizontal collaboration seeks to generate synergies between actors that are at the same level of the supply chain. Just as in the case of competitors or specifically as it is addressed in this work among producers so that they achieve greater benefits when integrated on horizontal collaboration. Senkel, Durand and Hoa [11] present cases among companies in the consumer sector where their results are positively affected. Becerra et al [12] contrasts the results between models of collaboration and non-collaboration with a common actor among the participants as is the logistics operator.

In particular, collaborative processes in the agricultural sector are addressed by several authors such as; Viera and Hartwich [13] who consider private-public alliances. Rojas [14] exposes the potential of the field through productive alliances. Kaplinsky [15], presents the agro business chains as a result of the alliances between actors with similar characteristics. Garza [16] indicates the importance of the beneficial relationships between the parties so that the agro chains are growth strategies.

On rural development, Vilches, Gil, Toscano and Macias [17] present collaborative processes as the way to guarantee the sustainability of the world based on environmental, cultural and productivity preservation. Naharro [18] indicates how regional policies should promote a self-sustaining environment focused on the rural world. David [19] presents the elements for a rural development strategy, a macroeconomic policy, a sectorial policy, and concrete actions to overcome rural poverty. Dwyer [20] addresses the economic, social and environmental components to implement rural development. Bonnal [21] highlights the importance of public policies to face the new challenges of globality and Romero, Olivar and Bianchi [22] simulate the performance of the agricultural sector of the potato in a situation of post-conflict and climate change.

Romero, Olivar and Bianchi [23] propose a model for the evaluation of public policies in the agricultural sector of the potato. The collaborative distribution centers developed through public-private partnerships and with the promotion and incentive of the government towards the producer, allow them to improve the measured performance in terms of product cost, harvested tons, and financial gross margin. After the design and simulation process a reduction of up to 15.6% in the cost of the product is obtained. The tons harvested can increase up to 11% and the financial gross margin presents an increase between 6 and 9 percentage points added to an increase in crop yield of 0.6 tons per hectare planted. Based on this model and the results obtained, elements necessary for the design of public policy are established. However it is of interest of this current research to reduce the level of uncertainty of the guidelines for their proper definition. This is carried out through sensitivity analysis, based on the identification and preliminary evaluation of the parameters of the model for further evaluation in a wider range. These parameters that act as levers of policy are precisely the time of agreement of the public-private relationship and the level of promotion of the model, where the first entails mainly a direct impact on the cost of the product and the second on the participation of the producer and the synergies achieved.

2 Dynamic Performance Management

Sustainable growth and performance management are relevant aspects for organizations. Precisely the methodology of dynamic performance management (DPM) through modeling with Systems Dynamics (SD) allows the design of planning and control mechanisms that facilitate decision-making. This considers the institutional development. This analyses the owner of the organization and other institutions with scope to the system in greater amplitude like a territory or economic sector [24]. This research uses dynamic performance management as the methodological framework. This is an instrumental view which accounts for identifying performance drivers that generate end results and how these end results affect strategic resources [25].

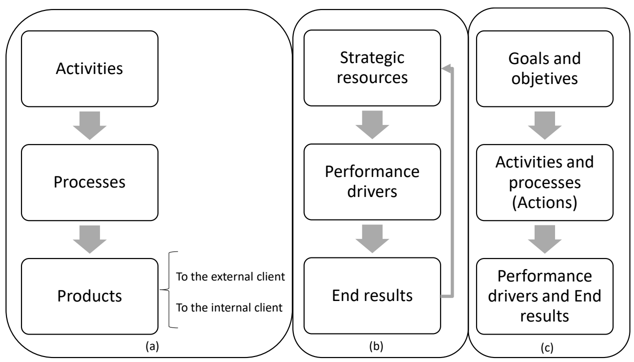


Fig. 1. Objective (a), Instrumental (b) and Subjective (c) view [26]

In the design of policies, levers are a fundamental element. These can be operated by the decision maker for the intervention in the system so that it is procured by a more efficient system. Through the simulation and the changes generated on the policy levers, it is possible to measure the depletion or accumulation of the strategic resources and the variables of interest. This supports the definition of guidelines that allow the adequate administration and evolution of the unit of interest.

For the agricultural sector of the potato in Colombia, the instrumental vision is established considering the collaborative public policy in distribution centers. This includes the levers of this policy for its later sensitivity analysis and definition of the parameters that improve the performance measures of the system.

The policy levers to intervene are those related to the implementation of collaborative logistics infrastructures. This includes distribution centers, being of interest to determine the contractual time of a public-private alliance for its management. Additionally, the level of promotion of the collaborative model related to the productive population that accesses the collaborative model, affects the aggregate performance of the sector.

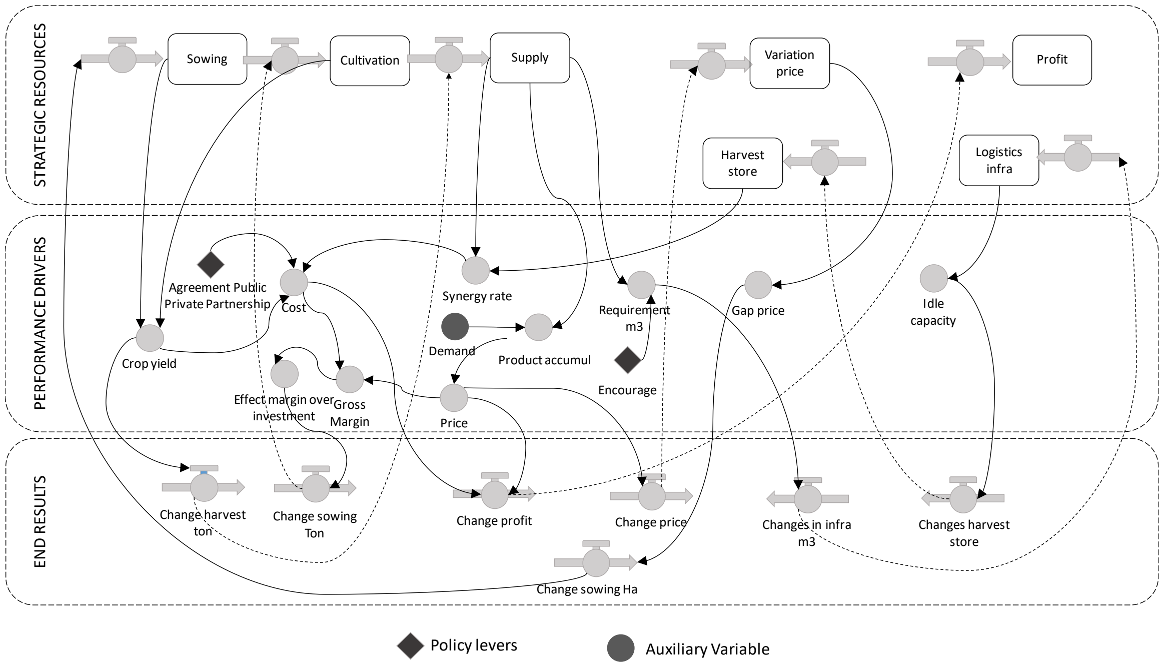


Fig. 2. **DPM for the analysis of the collaborative policy in the agricultural sector of the potato based on Romero et al. [23]**

3 Modeling the System

The system of the agricultural sector of the potato is modeled from an aggregate planning by type of producer. It is analysed in its various stages using the technique of SD in order to understand the causal relationships, the effects of delays, and feedback of the behaviours. In this session we present the causal loops diagram, the sectors of the model, and verification of the model.

3.1 Causal Loop Diagram

The relationships and feedback loops of the system are presented in the causal diagram, identifying the policies levers that will be intervened for the evaluation of the system´s performance:

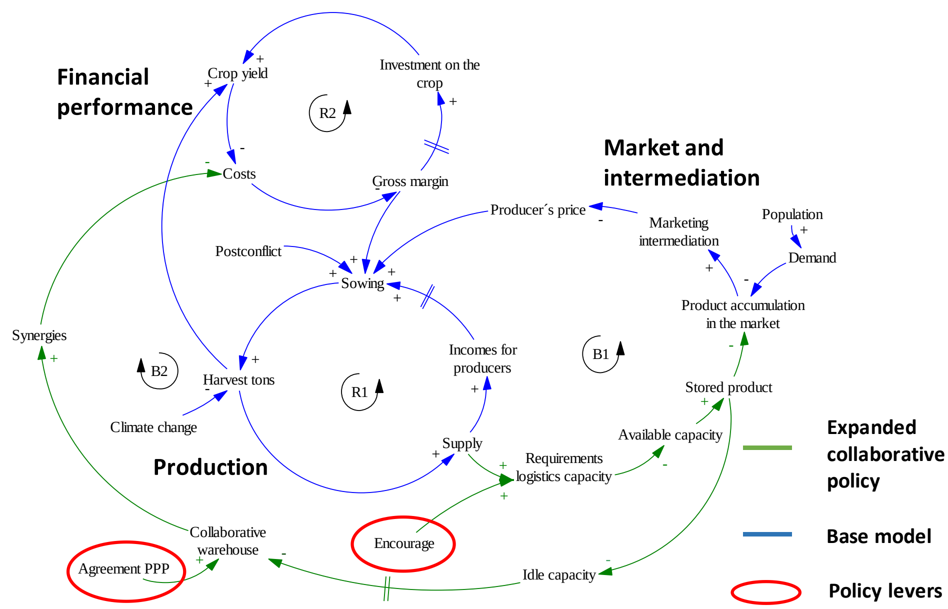


Fig. 3. **Causal loop diagram of the agricultural sector of the potato with emphasis on policy levers**

3.2 Sectors of the model

The modeled sectors correspond to production, market intermediation, and financial performance. The production sector has the extension of the capacity developed by the distribution centers as shown in the following figure:

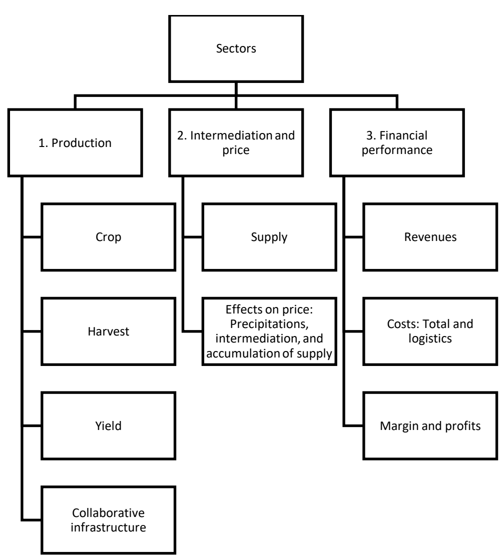


Fig. 4. **Sectors of the model**

Equations related to policy levers

The equations of the model based on Romero, Bianchi and Olivar [23], in addition, to those related to strategic resources, performance drivers, and end results, consider the equations associated with the policy levers. Such as; the time of the public-private partnership (TPPP) for the administration of the collaborative distribution centers and the level of promotion of the model by the State towards the producer (ENC).

- **Change for infrastructure return (RRWH):**

$$RRWH = \begin{cases} IDC_t, \text{time} \geq \text{TPPP} \ \wedge IDC_t > SZM \\ 0, otherwise \end{cases} \quad (16)$$

$$where$$
$$TPPP: agreement\ time\ of\ the\ public - private\ partnership$$
$$IDC_t: Idle\ capacity\ of\ period\ t$$

- **Cost of the cubic meter (m^3)** of storage after the public-private alliance, is represented by the effect shown in figure 5 and whose equation can be described as:

$$Cost\ m^3 = -64(\text{TPPP})^2 - 320(TPPP) + 35200 \quad (17)$$

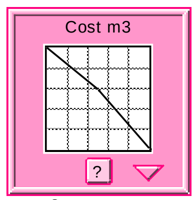


Fig. 5. **Behaviour of the cost per m^3 depending on the contractual time of the public-private partnership**

- **Requirement of cubic meters for storage (SMR)**

$$SMR = \text{SP} * \text{CTCM} * \text{ENC}$$

$$Where$$
$$ENC: Encourage, \quad level\ of\ encouragement\ by\ the\ State$$
$$CTCM: Equivalent\ of\ tons\ to\ cubic\ meters$$

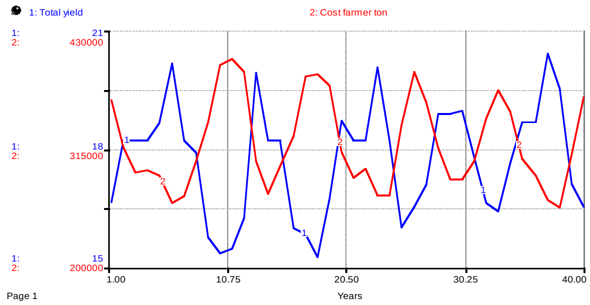
3.3 Verification of the model

The verification of the model related to the sensitivity analysis on the policy levers seeks to evaluate the suitability of the model by following a logical behaviour despite the variations in the time parameters of the private public alliance and the level of promotion of the model by the government towards the producer.

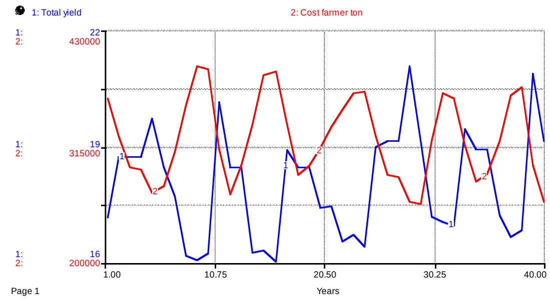
The logical behaviour of the model is verified through the simulation of the variables of cost, performance, supply, price, and planting. The verification graphs represent: (a) base behaviour, (b) the behaviour after the variation of the time of the public-private alliance and (c) the behaviour varying the time of the public-private alliance and the promotion level of the model.

Verification of crop yield and cost

To the extent that crop yield increases the cost of the product decreases due to increased productivity. Figure 6 shows that despite the change in the parameters in the public-private alliance and the promotion level of the model the behaviour of the variables is consistent.



(a)



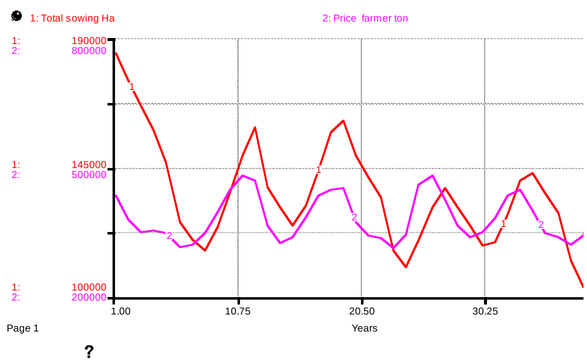
(b)

(c)

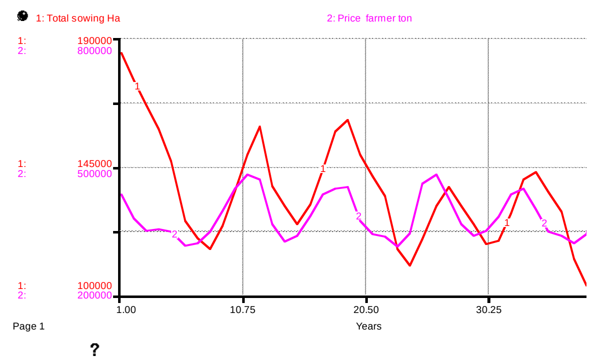
Fig. 6. Verification of the performance and cost of the product

Price verification and planting

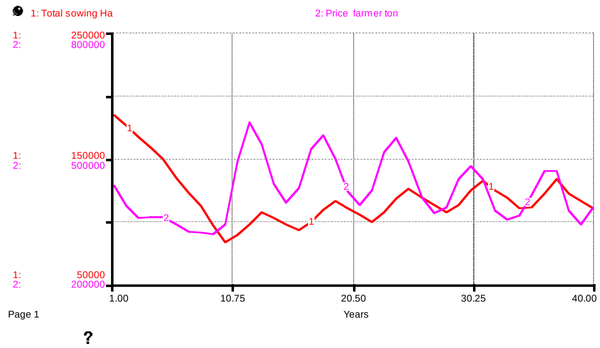
The price perceived by the producer affects his decision on the hectares to be planted in the next period, i.e. the decision is made with a delay associated with the flow of information, shows that figure 7.



(a)



(b)

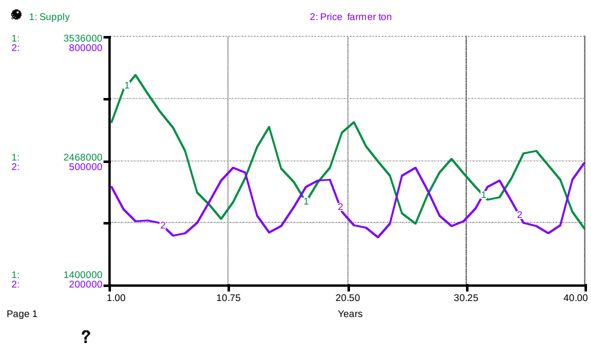


(c)

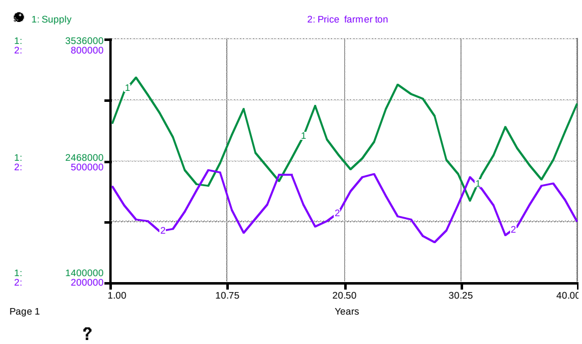
Fig. 7. **Verification of hectares planted and price**

Verification of price and supply

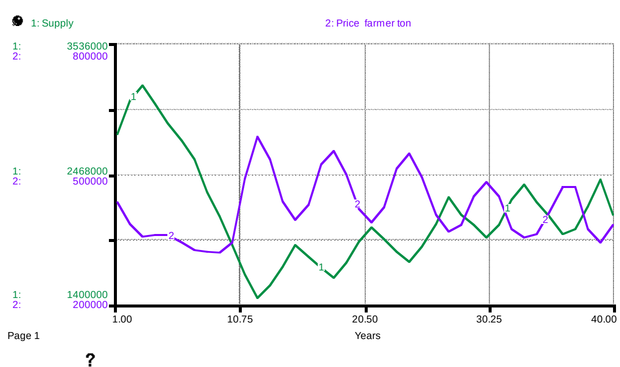
The accumulation of product supply affects the price that will be paid to the producer. Given the high availability of product in the market the price decreases and vice versa, shows that figure 8.



(a)



(b)



(c)

Fig. 8. **Verification of the supply and price**

4 Results

The sensitivity analysis is carried out on the policy levers, based on the results obtained by Romero, Olivar and Bianchi [23]. This shows that the best performance of the potato agricultural sector with the implementation of the collaborative public policy in distribution centers, is obtained when the public-private partnership exceeds 15 years and a moderate promotion (up to 50% of the producers population) by the government. This was due to better cost management, decreased idle capacity and decentralized distribution centers that respond to the requirements of the network.

However, it is of interest to incentive these results and that they lead to adequate policy guidelines so the importance of a sensitivity analysis to determine the parameters that reinforce the desired behaviour of the system, which also considers climate change situation and post armed conflict.

4.1 Policy levers

Based on the definition of a public-private partnership greater than 15 years and a level of encouragement that reaches up to 50% of the production population (scenario S1). The parameters considered are defined below:

Table 1. Sensitivity analysis scenarios

	Scenario							
Policy Levers	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Public – Private Parnertship=15	X				X			
Public – Private Parnertship=20		X				X		
Public – Private Parnertship=25			X				X	
Public – Private Parnertship=30				X				X
Encouragement: 0.3		X	X	X	X			
Encouragement: 0.5	X					X	X	X

4.2 Yield, cost, production and gross margin

The yield of the crop is the ratio obtained between the tons harvested in the hectares planted, thus determining the efficiency of the process and which is considered a fundamental factor in the agricultural sector as a measure of competitiveness. A greater yield of the crop leads to a better use of the resources and therefore to a better cost. After analysing the sensitivity of the 8 scenarios their behaviour is observed summarized through the 95% confidence interval and its average.

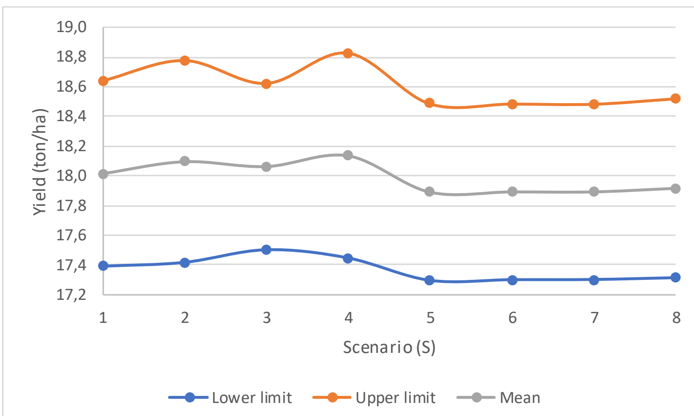


Fig. 9. Contrast crop yield

In figure 9, the base scenario represented as S1 is exceeded in its performance up to 0.7% by making changes in the public-private alliance at 30 years and a promotion level of 30%.

As for the cost of the product, it can be improved according to the results up to 0.75% as a result of a public-private alliance at 25 years and a promotion level of 30%, see figure 10.

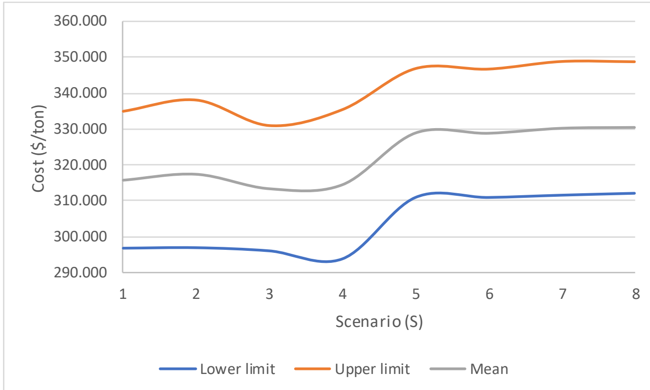


Fig. 10. Contrast scenarios of product cost per ton

As for the financial gross margin, an increase of up to 0.6 percentage points is reached. That is an improvement of up to 2.28% (see figure 11). The above calculated on a homogenous base price.

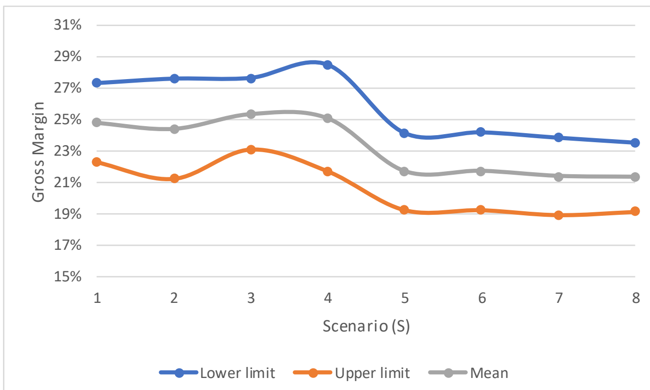


Fig. 11. Contrast of financial gross margin scenarios.

4.3 Multi-dimensional analysis

Given the interest to determine those parameters that can incentive the performance of the agricultural producers of the potato, the multi-dimensional analysis is carried out to comprehensively analyse the strategy and to allow adequate public policy guidelines.

Table 3. Contrast scenarios

Variable	*Scenario*							
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Cost	315.713	317.344	313.340	314.442	328.762	328.698	330.077	330.311
Yield	18,01	18,10	18,06	18,14	17,89	17,89	17,89	17,92
Supply (thousands)	40.569	37.942	39.042	37.698	37.222	37.334	37.319	37.729
Gross Margin	24,8%	24,4%	25,4%	25,1%	21,7%	21,7%	21,4%	21,3%

The valuation is made considering the results of cost, yield, gross financial margin, and an additional variable related to the product that will be supplied. These evaluate each item with the same weight and on a scale of 0, 1, 3 and 5, where 0 is the lowest performance and 5 the highest. As mentioned, each variable is given the same weight starting from the assumption of equal importance for the development of the sector.

The scenarios considered are S1, S2, S3 y S4, because they have the best behaviour as shown in the table 3:

Table 3. Scenarios assessment

Variable	*Scenario*							
Variable	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Cost	1	-	5	3	-	-	-	-
Yield	-	3	1	5	-	-	-	-
Supply	5	1	3	-	-	-	-	-
Gross Margin	-	1	5	3	-	-	-	-
Total score	**6**	**5**	**14**	**11**	**-**	**-**	**-**	**-**

Scenario S3 obtains the highest score defining the proposed guidelines to consider in public policy that incentivises the development of the agricultural sector of the potato, measured through the variables of product cost, crop yield, product supply, and gross financial margin perceived by the producer.

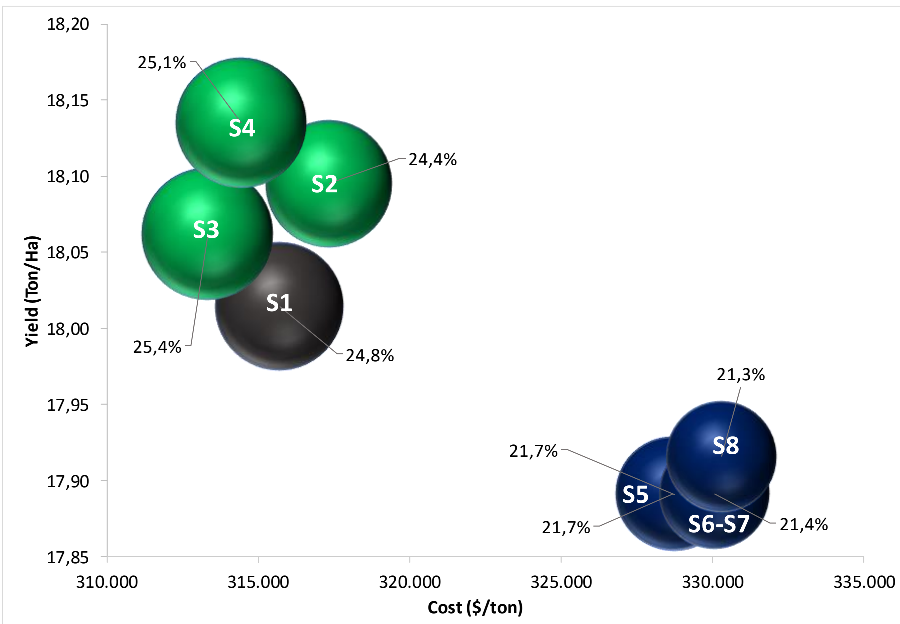


Fig. 12. Multi-dimensional analysis with the intervention of the policy levers

Scenario S3 presents both analytically and graphically the highest levels of performance analyzed in a consolidated way, represented by a public private alliance of 25 years and a promotion that encourages the segmentation of producers without exceeding 30% of the population for each collaborative distribution center, maintaining a decentralized network by geographic coverage but allowing synergies between producers in the region.

Conclusions

The design of public policies is the fundamental basis for a successful implementation. However, the decision-making process is naturally tied to certain levels of uncertainty and that is precisely where the modeling and analysis based on the dynamics of systems. This allows us to understand with greater precision their possible behaviours when simulated. The agricultural sector has been the scene of multiple studies that seek to increase their competitiveness, where economic, social, environmental, and even cultural interests are combined. This research focuses on the agricultural sector of the potato in Colombia, adding the production by type of producer so that the overall performance is the sum of the group performances starting from a previous policy guideline. This shows us that it is possible to improve the cost of the product, the yield of the crop, and the financial gross margin. It is possible to balance supply and demand and to give greater empowerment to the producer through the development of a horizontal collaborative strategy with central axis in the distribution centers, which triggers best practices for increasing its competitiveness.

Based on the basic guidelines, the sensitivity analysis allows us to explore a broad spectrum of possible parameters that modify, but above all, enhance the performance of the sector. The simulated policy levers make reference to the time of the public-private partnership for the operation of the collaborative distribution centers and the level of promotion for the participation of the producers and subsequent synergies. These elements are operated by the decision-makers. The simulation shows the best performance with a public-private alliance of 25 years and promotion of up to 30% on the producers.

These results show significant improvements in the performance of the producers that have an impact on the market. When contrasted with the system without the assumption of implementing the collaborative policy, it changes the reduction of costs up to 8%, an increase in performance of 3%, an increase in the product offer by 6%, and a better financial margin of up to 6.6 percentage points. This generates a balance in the market by managing supply and demand levels, decreasing product accumulation, and encouraging investment to raise the productivity of the crop. That is, it produces a more competent, more strategic and less subsidized producer.

The modeling of public policies thus becomes a strategic instrument based on a good understanding of the causal relationships in the system and the elements that may affect its performance. This design and subsequent implementation obey the collective needs , guaranteeing the support to the interior of the affected entities, and inter-institutionally to the sector or territory intervened.

References

1. World Bank, Homepage, http://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=CO, last accessed 2018/09/24.
2. World Bank, Homepage, ttps://datos.bancomundial.org/indicador/NV.AGR.TOTL.ZS?locations=CO, last accessed 2018/09/24.
3. National Planning Department (DPN): Plan Nacional de Desarrollo 2006-2010, Bogotá, (2007).
4. National Planning Department (DPN): Plan Nacional de Desarrollo 2010-2014, Bogotá, (2011).
5. National Planning Department (DPN): Plan Nacional de Desarrollo 2014-2018, Bogotá, (2015).
6. Organización para la Cooperación y el Desarrollo Económico (OCDE): Review of Agricultural Policies, Bogotá, (2015).
7. National Administrative Department of Statistics (DANE), National Agricultural Census 2014, Bogotá (2014).
8. Simatupang, T.: Applying the theory of constraints to supply chain collaboration Supply Chain Management. An International Journal, (2004).
9. Stefansson, G.: Collaborative logistics management and the role of third-party service providers. International Journal of Physical Distribution & Logistics Management, vol. 36, nº 2, pp. 76-92 (2006).
10. Mentzer, J., Kenneth, M.: Demand collaboration: effects on knowledge creation, relationships, and supply chain performance. Journal of Business Logistics, vol. 27, nº 2, pp. 191-221 (2011).
11. Senkel, M., Durand, B., Hoa, T.: La Mutualisation logistique: entre théories et pratiques. Logistique and Management, vol. 21, nº 1, pp. 19-30 (2013)
12. Becerra, M., González, C., Herrera, M., Romero, O.: Collaborative planning capacities in distribution centers. In: Theory, methodology, tools and applications for modeling and simulation of complex systems: 16th Asia

Simulation Conference and SCS Autumn Simulation Multi-Conference, AsiaSim/SCS AutumnSim, Proceedings, Part I, pp. 622-632, Beijing, China (2016).
13. Viera, L., Hartwich F.: Approaching puiblic-private partnership for agroindustrial research: A methodological framework. San José, Costa Rica (2002).
14. Rojas, M.: Productive alliances as an instrument of rural development in Colombia. In: Policies, instruments and experiences of rural development in Latin America and Europe. Ministry of Agriculture, Fisheries and Food of Spain, Madrid (2002).
15. Kaplinsky, R.: Spreading the gains from globalization: What can be learned from value chain analysis?. Problems of Economic Transition 47(2), 74-115 (2014).
16. Garza, F.: Public-private partnerships for research and development in agroindustrial chains: The situation in El Salvador. ISNAR, San José (2003).
17. Vilches, A., Gil D., Toscano J., Macías, O.: Rural development and sustainability (2014), http://www.oei.es/decada/accion.php?accion=22, last accessed, 2018/03/21.
18. Naharro, M.: Rural development and sustainable development. The ethical sustainability. Ciriec, Public, Social and Cooperative Economy Journal (55), 7-42 (2006)
19. M. B.: Desarrollo rural y desarrollo sostenible. La sostenibilidad ética, Bogotá: Alfaomega, 2001.
20. Dwyer, J.: Review of rural development instrument. University of Gloucestershire, London (2008).
21. 21. Bonnal, P.: Multifuncionalidad de la Agricultura y Nueva Ruralidad": Reestructuración de las políticas públicas a la hora de la globalización. Fundación Tierra (2003).
22. Romero, O., Olivar G., Bianchi, C.: Dynamic Performance of the Agricultural Sector Under Conditions of Climate Change and Armed Post-conflict. Applied Computer Sciences in Engineering. WEA 2018. Communications in Computer and Information Science, vol. 915, pp. 292-304 (2018).
23. Romero, O., Olivar G., Bianchi, C.: Modeling Collaborative Logistics Policies that Impact the Performance of the Agricultural Sector. Applied Computer Sciences in Engineering. WEA 2018. Communications in Computer and Information Science, vol. 915, pp. 377-389 (2018).
24. Bianchi C.:Enhancing performance management and sustainable organizational growth through System-Dynamics Modeling. In Systemic Management for Intelligent Organizations: Concepts, Models-Based Approaches and Applications. Springer Berlin Heidelberg. inbook, pp. 143-161 (2012).
25. Bianchi, C., Dynamic Performance Management. Springer International Publishing, Switzerland (2016).
26. Bianchi C.: Improving Performance and Fostering Accountability in the Public Sector through System Dynamics Modeling: From an 'external' to an 'internal' Perspective. Systems Research and Behavioral Science, pp. 361-384 (2010)
27. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17

CONCLUSIONS

Potatoes are one of the most widely consumed foods in the world and easily accessible to the poorest, being a key product to meet the increasingly growing food needs, where the agricultural producer is the central axis to achieve this purpose. However, the reality of the sector shows a great dispersion in the favourable conditions for the farmer, where the small-sized producer dominates, sensitive to both market and environmental variations, given the low level of investment and technology constraining sustainable growth.

Among the multiple factors that surround the potato sector, the effects of climate change and the condition of armed post-conflict are analysed simultaneously, with the expectation of opposite behaviours. Climate change threatens to reduce the yield of the crop, and after the armed post-conflict a growth of the sector is projected, as a consequence of a lesser desertion of the field, greater investment, better social conditions and a greater presence of the state. When analysing the conjugation of these factors and after the multidimensional evaluation of the performance of the producers and the sector, it is observed that the actions that are unleashed at the level of the armed post-conflict represent an important contribution on the development of the sector. However, it is counteracted by the effect of climate change, indicating that for a true boom in the sector, strategies with specific focus should be developed, following a central development plan.

When analysing the scenario with the highest probability of occurrence, presence of climatic change and armed post-conflict conditions, it shows a slight rebound in the variables of interest, 1.2% increase in crop yield, a 1.4% decrease in the cost per ton, an increase of 1.3 percentage points in the gross financial margin, plus stability in the hectares planted. Although this scenario shows a better behaviour in contrast to the scenario without climate change and armed conflict, the results show a fairly moderate growth when compared with countries such as China, India and the United States, reaching unfavourable deviations for Colombia. For example, higher product prices between 50% and 65% and lower yield in tons harvested per hectare up to 15%. That is, low performance persists in comparison with other markets, highlighting the need to promote actions of both the public and private sectors. This leverages real development of producers and the sector in general, making it more competitive and with the faculty of addressing challenges of greater globality, even surpassing the national context.

We understand the situation of the potato sector and the effect of armed post-conflict and climate change. The impact of horizontal logistics collaboration through distribution centers in the potato agricultural sector allows for the evaluation of public policy instruments and to improve the farmers performance, using a multidimensional analysis of the variables associated with production, market, intermediation, and financial performance.

The methodology applied to understand the causal relationships is DPM. The identification of strategic resources, drivers performance and end results, facilitate the understanding of their interaction for the evaluation of the elements associated with the public policies. This is how the strategic resources of the system are related to the planting and harvesting of the product, the offer, the price variation and the profits obtained by the producer, but with the intervention of public policy, is extended with specialized infrastructures, as are the collaborative distribution centers.

Public policy starts from the premise of the development of public private alliances. The time agreed upon between the parties affects the performance of the sector and, according to the modeling, better results are obtained when public private alliances exceed 15 years, given the stability that exists, positively impacting the costs per ton. The promotion from the State towards the producer affects the level of commitment and interest of this actor and where a moderate level of promotion leads to the best results. This encourages a sustainable coverage of the infrastructure of the collaborative warehouses and their permanent occupancy . For the case of this work, it supposes a moderate level of promotion of the model reaching up to 50% of farmers. Despite being counterintuitive, this is acceptable by the times required for the implementation of infrastructures, the sensitivity of idle capacity over financial performance and the uncertainty of crop yield associated with climate change.

This shows the need to open several distribution centers , through an adequate logistics network, the productive, geographic and product distribution requirements, acting as decentralized physical nodes.

The agricultural producer of the potato has gross financial margins that range between 15% and 18% [26], with a high degree of involvement for the commercialization of the product until reaching the consumer, including around seven additional actors. These actions do not generate value in all cases, but do affect the reduction of the profits and economic sustainability of the producer, as well as a higher payment by the consumer that is not received by the producer. With the approach of the horizontal logistics collaboration between producers through the distribution centers, the financial margins are improved reaching an increase between 6 and 9 points. The need for intermediation decreases and a better balance between supply and demand is achieved. The synergies achieved allow economies of scale that favour the level of investment on the crop to obtain higher yields in the harvest. The number of tons harvested show growth of up to 11%. After the analysis with the assumption of implementation of the collaborative public policy, which is associated with a higher crop yield, it would go from generating in average 17.6 tons/hectare to 18.2 tons/hectare. This results in a higher profitability, more incentive to invest and cultivate.

Production costs are positively impacted despite the generation of new costs related to the collaborative logistics of the distribution centers because the simulation does not suppose a subsidized model. The producer must pay to access specialized infrastructure offset by the agreements between farmers and whose benefits are mainly due to the balance reached between supply and demand, and decisive pricing. The cost presents a savings of up to 15.6%, allowing the producer more flexibility and access to new markets, in a sustainable and profitable manner.

Based on the basic guidelines, the sensitivity analysis allows us to explore a broad spectrum of possible parameters that modify, above all, enhancing the performance of the sector. The simulated policy levers make reference to the time of the public-private partnership for the operation of the collaborative distribution centers and the level of encouragement for the participation of the producers and other players. These elements are operating by the decision-makers. The simulation shows that the best performance with a public-private alliance will occur after 25 years and incentvices up to 30% on the producers.

These results show significant improvements in the performance of the producers that have an impact on the market and that when contrasted with the system without the assumption of implementing the collaborative policy, it reduces the costs up to 8%, increases in performance up to 3%, increases the supply by 6% , and a better financial margin of up to 6.6 percentage points. This generates a balance in the market by managing supply and demand levels, decreasing product accumulation and encouraging investment to raise the productivity of the crop, that is, a more competent, more strategic and less subsidized producer.

The modeling of public policies thus becomes a strategic instrument, based on a good understanding of the causal relationships in the system and the elements that may affect its performance.That design and subsequent implementation attend to the collective needs , guaranteeing support to the effective entities on and off the farm.

On the other hand, it is not possible to talk about rural development, without thinking about the development of the agricultural producer. Therefore the actions generated for the intervention of the sector should be strategically focused on its competitiveness, guaranteeing the sustained rise of its economic, social and environmental realities. So this work starts from the characterization of the producer and its performance over time, showing that collaborative relationships foster their development and therefore the associated environment, through a system based on productivity. This achieves greater competition that potentializes access to new markets and not a protectionist system that limits the development of the sector.

REFERENCES

Abstract

1. Food and Agriculture Organization of the United Nations: FAO's work on climate change. FAO (2015).
2. International Food Policy Research Institute IFPRI: Climate change, Washington D.C (2009).
3. National Administrative Department of Statistics (DANE), National Agricultural Census 2014, Bogotá (2014).
4. National Administrative Department of Statistics (DANE), Monetary and Multidimensional Poverty: Main results 2014, Bogotá (2015).
5. Agricultural Society of Colombia, Situation and perspectives of agriculture in Colombia, Bogotá (2016).
6. R. Semana, «Así es la Colombia rural,» Revista Semana, 2012.
7. Food and Agriculture Organization of the United Nations, « New light on a hidden a treasure: World food and agriculture,» FAO, Rome, 2008.
8. Food and Agriculture Organization of the United Nations, «Statistical Pocketbook: World food and agriculture,» FAO, Rome, 2015.
9. Food and Agriculture Organization of the United Nations., «FaoStat,» Food and Agriculture Organization of the United Nations., 2015. [En línea]. Available: http://faostat3.fao.org/browse/Q/QC/E. [Último acceso: 12 June 2016].
10. Agrocadenas Observatory Colombia: The potato chain in Colombia, Bogotá (2005).
11. J. Barrientos, C. Rondón y S. Melo, «Price performance of the potato varieties Parda Pastusa and,» Revista Colombiana de Ciencias Hortícolas, vol. 8, nº 2, pp. 272-286, 2014.
12. Corpoica, «Corpoica,» 2008. [En línea]. Available: http://corpomail.corpoica.org.co/BACFILES/BACDIGITAL/55508/55508.pdf. [Último acceso: 12 06 2016].
13. Organización para la Cooperación y el Desarrollo Económico (OCDE), «Review of Agricultural Policies: Colombia 2015.,» OCDE, 2015.

Chapter 1: Dynamic performance of the agricultural sector under conditions of climate change and armed post-conflict

1. National Administrative Department of Statistics (DANE), National Agricultural Census 2014, Bogotá (2014).
2. National Administrative Department of Statistics (DANE), Monetary and Multidimensional Poverty: Main results 2014, Bogotá (2015).
3. Agricultural Society of Colombia, Situation and perspectives of agriculture in Colombia, Bogotá (2016).
4. Food and Agriculture Organization of the United Nations: FAO's work on climate change. FAO (2015).
5. International Food Policy Research Institute IFPRI: Climate change, Washington D.C (2009).
6. Food and Agriculture Organization of the United Nations - Ministry of Agriculture: Use of the AquaCrop model to estimate yields for potato cultivation in the departments of Cundinamarca and Boyacá. FAO, Bogotá (2013).
7. Woli P., Hoogenboom, G.: Simulating weather effects on potato yield, nitrate leaching, and profit margin in the US Pacific Northwest. Agricultural Water Management, vol. 201, pp. 177-187 (2018).
8. Adavi Z., Moradi R., Tadayon M., Mansouri H.: Assessment of potato response to climate change and adaptation strategies. Scientia Horticulturae, vol. 228, pp. 91-102 (2018).
9. Dua V., Sharma J.: Forecasting impact of climate change on potato productivity in west Bengal and adaptation strategies. Indian Journal of Horticulture, vol. 74 (4), pp. 533-540 (2017).
10. Raymundo R., Asseng S., Kleinwechter U., Concha J., Condori B., Bowen W., Wolf J., Olesen J., Dong Q., Zotarelli L., Gastelo M., Alva A., Travasso M., Quiroz R., Arora V., Graham W., Porter C.: Performance of the SUBSTOR-potato model across contrasting growing conditions. Field Crops Research, vol. 202, pp. 57-76 (2017).
11. Deguchi T., Iwama K., Haverkort A.: Actual and potential yield levels of potato in different production systems of Japan. Potato research, vol. 59 (3), pp. 207-225 (2016).
12. Kleinwechter U., Gastelo M., Ritchie J., Nelson G., Asseng S.: Simulating cultivar variations in potato yields for contrasting environments. Agricultural Systems, vol. 145, pp. 51-63 (2016).
13. National Planning Department (DPN): Economic dividend for peace, Bogotá, (2015).

14. Santa Maria M., Rojas N., Hernández G., Economic growth and armed conflict in Colombia, Bogotá (2013).
15. Alvárez S., Rettberg A.: Quantifying the economic effects of conflict: An exploration of the costs and the studies on the costs of the colombian armed conflict. Colombia Internacional 67, pp. 14-37 (2008).
16. Ibáñez A., Velásquez A.: The impact of forced displacement in Colombia: socio-economic conditions of the displaced population, linkage to labor markets and public policies. CEPAL, Series social policies, Santiago de Chile (2008).
17. Hewitt N., Gantiva C., Vera A., Cuervo M. , Hernández N., Juarez F., Parada A.: Psychological effects on children and adolescents exposed to armed conflict in a rural area of Colombia. Acta Colombiana de Psicología, vol. 17, pp. 79-89 (2014).
18. Bell V., Méndez F., Martínez C., Palma P., Bosch M.: Characteristics of the colombian armed conflict and the mental health of civilians living in active conflict zones. Conflict and Health, vol. 6 (1), pp. 1-8 (2012).
19. Llosa A., Casas G., Thomas H., Mairal A., Grais R, Moro M.: Short and longer-term psychological consequences of operation cast lead: documentation from a mental health program in the Gaza Strip. Conflict and Health, vol. 6 (1), pp. 1-10 (2012).
20. Bianchi C.:Enhancing performance management and sustainable organizational growth through System-Dynamics Modeling. In Systemic Management for Intelligent Organizations: Concepts, Models-Based Approaches and Applications. Springer Berlin Heidelberg. inbook, pp. 143-161 (2012).
21. Cosenz F.: Supporting start-up business model design through system dynamics modeling. Management decision, vol. 55 (1), pp. 57-80 (2017)
22. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17.
23. Food and Agriculture Organization of the United Nations (FAO): Use of the AquaCrop model to estimate agricultural yields in Colombia. FAO, Bogotá D.C. (2013).

Chapter 2: Modeling collaborative logistics policies that impact the performance of the agricultural sector

1. World Bank, Homepage, http://data.worldbank.org/topic/agriculture-and-rural-development, last accessed 2016/05/05.
2. Food and Agriculture Organization of the United Nations: Statistical Pocketbook: World food and agriculture. FAO, Rome (2015).
3. Vilches, A., Gil D., Toscano J., Macías, O.: Rural development and sustainability (2014), http://www.oei.es/decada/accion.php?accion=22, last accessed, 2018/03/21.
4. Naharro, M.: Rural development and sustainable development. The ethical sustainability. Ciriec, Public, Social and Cooperative Economy Journal (55), 7-42 (2006)
5. David, M.: Rural development in Latin America and the Caribbean: the construction of a new model?. CEPAL-Alfaomega, Bogotá (2001).
6. Dwyer, J.: Review of rural development instrument. University of Gloucestershire, London (2008).
7. Viera, L., Hartwich F.: Approaching puiblic-private partnership for agroindustrial research: A methodological framework. San José, Costa Rica (2002).
8. Rojas, M.: Productive alliances as an instrument of rural development in Colombia. In: Policies, instruments and experiences of rural development in Latin America and Europe. Ministry of Agriculture, Fisheries and Food of Spain, Madrid (2002).
9. Kaplinsky, R.: Spreading the gains from globalization: What can be learned from value chain analysis?. Problems of Economic Transition 47(2), 74-115 (2014).
10. Garza, F.: Public-private partnerships for research and development in agroindustrial chains: The situation in El Salvador. ISNAR, San José (2003).
11. Ariño, A.: Strategic alliances: Options for the growth of the company. In: Financial strategy, vol 236, pp. 40-51 (2007).
12. Burgers, W., Hill, C., Kim, C.: A theory of global strategic alliance: The case of the global auto industry. Strategic management journal 14(6), 419-432 (1993).
13. Becerra, M., González, C., Herrera, M., Romero, O.: Collaborative planning capacities in distribution centers. In: Theory, methodology, tools and applications for modeling and simulation of complex systems: 16th Asia Simulation Conference and SCS Autumn Simulation Multi-Conference, AsiaSim/SCS AutumnSim, Proceedings, Part I, pp. 622-632, Beijing, China (2016).

14. Bianchi, C., Dynamic Performance Management. Springer International Publishing, Switzerland (2016)
15. Agrocadenas Observatory Colombia: The potato chain in Colombia, Bogotá (2005).
16. National Administrative Department of Statistics (DANE): National Agricultural Census 2014, Bogotá (2014).
17. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17.

Chapter 3: Guidelines for collaborative public policy in the agricultural sector, based on the analysis of dynamic sensitivity

1. World Bank, Homepage, http://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=CO, last accessed 2018/09/24.
2. World Bank, Homepage, ttps://datos.bancomundial.org/indicador/NV.AGR.TOTL.ZS?locations=CO, last accessed 2018/09/24.
3. National Planning Department (DPN): Plan Nacional de Desarrollo 2006-2010, Bogotá, (2007).
4. National Planning Department (DPN): Plan Nacional de Desarrollo 2010-2014, Bogotá, (2011).
5. National Planning Department (DPN): Plan Nacional de Desarrollo 2014-2018, Bogotá, (2015).
6. Organización para la Cooperación y el Desarrollo Económico (OCDE): Review of Agricultural Policies, Bogotá, (2015).
7. National Administrative Department of Statistics (DANE), National Agricultural Census 2014, Bogotá (2014).
8. Simatupang, T.: Applying the theory of constraints to supply chain collaboration Supply Chain Management. An International Journal, (2004).
9. Stefansson, G.: Collaborative logistics management and the role of third-party service providers. International Journal of Physical Distribution & Logistics Management, vol. 36, nº 2, pp. 76-92 (2006).
10. Mentzer, J., Kenneth, M.: Demand collaboration: effects on knowledge creation, relationships, and supply chain performance. Journal of Business Logistics, vol. 27, nº 2, pp. 191-221 (2011).
11. Senkel, M., Durand, B., Hoa, T.: La Mutualisation logistique: entre théories et pratiques. Logistique and Management, vol. 21, nº 1, pp. 19-30 (2013)
12. Becerra, M., González, C., Herrera, M., Romero, O.: Collaborative planning capacities in distribution centers. In: Theory, methodology, tools and applications for modeling and simulation of complex systems: 16th Asia Simulation Conference and SCS Autumn Simulation Multi-Conference, AsiaSim/SCS AutumnSim, Proceedings, Part I, pp. 622-632, Beijing, China (2016).
13. Viera, L., Hartwich F.: Approaching puiblic-private partnership for agroindustrial research: A methodological framework. San José, Costa Rica (2002).
14. Rojas, M.: Productive alliances as an instrument of rural development in Colombia. In: Policies, instruments and experiences of rural development in Latin America and Europe. Ministry of Agriculture, Fisheries and Food of Spain, Madrid (2002).
15. Kaplinsky, R.: Spreading the gains from globalization: What can be learned from value chain analysis?. Problems of Economic Transition 47(2), 74-115 (2014).
16. Garza, F.: Public-private partnerships for research and development in agroindustrial chains: The situation in El Salvador. ISNAR, San José (2003).
17. Vilches, A., Gil D., Toscano J., Macías, O.: Rural development and sustainability (2014), http://www.oei.es/decada/accion.php?accion=22, last accessed, 2018/03/21.
18. Naharro, M.: Rural development and sustainable development. The ethical sustainability. Ciriec, Public, Social and Cooperative Economy Journal (55), 7-42 (2006)
19. M. B.: Desarrollo rural y desarrollo sostenible. La sostenibilidad ética, Bogotá: Alfaomega, 2001.
20. Dwyer, J.: Review of rural development instrument. University of Gloucestershire, London (2008).
21. 21. Bonnal, P.: Multifuncionalidad de la Agricultura y Nueva Ruralidad": Reestructuración de las políticas públicas a la hora de la globalización. Fundación Tierra (2003).
22. Romero, O., Olivar G., Bianchi, C.: Dynamic Performance of the Agricultural Sector Under Conditions of Climate Change and Armed Post-conflict. Applied Computer Sciences in Engineering. WEA 2018. Communications in Computer and Information Science, vol. 915, pp. 292-304 (2018).

23. Romero, O., Olivar G., Bianchi, C.: Modeling Collaborative Logistics Policies that Impact the Performance of the Agricultural Sector. Applied Computer Sciences in Engineering. WEA 2018. Communications in Computer and Information Science, vol. 915, pp. 377-389 (2018).
24. Bianchi C.:Enhancing performance management and sustainable organizational growth through System-Dynamics Modeling. In Systemic Management for Intelligent Organizations: Concepts, Models-Based Approaches and Applications. Springer Berlin Heidelberg. inbook, pp. 143-161 (2012).
25. Bianchi, C., Dynamic Performance Management. Springer International Publishing, Switzerland (2016).
26. Bianchi C.: Improving Performance and Fostering Accountability in the Public Sector through System Dynamics Modeling: From an 'external' to an 'internal' Perspective. Systems Research and Behavioral Science, pp. 361-384 (2010)
27. Food and Agriculture Organization (FAO) Homepage, http://www.fao.org/faostat/en/#data/QC/visualize, last accessed 2017/09/17

APPENDIX A (POTATO´S SECTOR MODEL)

Demand and price

Supply(t) = Supply(t - dt) + (Harvest_Year_SFarmer + Harvest_year_MFarmer + Harvest_year_BFarmer - Harvest_shipment_depedent_on__the_intermedary - Harvest_shipment_dependent_on_the_farmers) * dtINIT Supply = 2800000

INFLOWS:

Harvest_Year_SFarmer (IN SECTOR: Production)

Harvest_year_MFarmer (IN SECTOR: Production)

Harvest_year_BFarmer (IN SECTOR: Production)

OUTFLOWS:

Harvest_shipment_depedent_on__the_intermedary = Supply*Intermediation_rate

Harvest_shipment_dependent_on_the_farmers = Supply*Rate_dependent__on_the_farmers

Variation_Price(t) = Variation_Price(t - dt) + (Current_Price - Last_Price) * dtINIT Variation_Price = 661000

INFLOWS:

Current_Price = Price__farmer_ton*Con_Ton_year

OUTFLOWS:

Last_Price = Variation_Price*Conv_year

Accumulation_product_rate = (Harvest_Year_SFarmer+Harvest_year_MFarmer+Harvest_year_BFarmer)/Demand

Comsuption_percapita = 0.0641

Con_Ton_year = 1

Demand = Domestic_consumption

Domestic_consumption = Comsuption_percapita*Population

Expected_margin = 0.20

Expected_price_farmer = -Cost_farmer_ton/(-1+Expected_margin)

incentive_demand = if(Change_climate_A2=1) or (Change_climate_B2=1) then if(Price_base_market<Expected_price_farmer) then 1.05 else 1 else 1

Intermediation_rate = 0.99*incentive_demand

Potencial_External__comsuption = 10000000

Price_base_market = 400000

Price__farmer_ton = if(Post_conflict__growth_mean=1) then Expected_price_farmer*Effect_intermed_post*Effect_on_price else Expected_price_farmer*Effect__intermedary*Effect_on_price

Rate_dependent__on_the_farmers = 1-Intermediation_rate

Effect_intermed_post = GRAPH(Intermediation_rate)

(0.99, 0.98), (0.995, 0.98), (1.00, 0.9)

Effect_on_price = GRAPH(Accumulation_product_rate)

(0.15, 0.00), (0.23, 1.58), (0.31, 1.45), (0.39, 1.40), (0.47, 1.30), (0.55, 1.25), (0.63, 1.05), (0.71, 0.98), (0.79, 0.92), (0.87, 0.98), (0.95, 0.98)

Effect__intermedary = GRAPH(Intermediation_rate)

(0.99, 0.95), (0.995, 0.95), (1.00, 0.9)

Population = GRAPH(TIME)

(1.00, 3.6e+007), (2.00, 3.7e+007), (3.00, 3.7e+007), (4.00, 3.8e+007), (5.00, 3.9e+007), (6.00, 3.9e+007), (7.00, 4e+007), (8.00, 4e+007), (9.00, 4.1e+007), (10.0, 4.1e+007), (11.0, 4.2e+007), (12.0, 4.2e+007), (13.0, 4.3e+007), (14.0, 4.3e+007), (15.0, 4.4e+007), (16.0, 4.4e+007), (17.0, 4.5e+007), (18.0, 4.6e+007), (19.0, 4.6e+007), (20.0, 4.7e+007), (21.0, 4.7e+007), (22.0, 4.8e+007), (23.0, 4.8e+007), (24.0, 4.9e+007), (25.0, 4.9e+007), (26.0, 5e+007), (27.0, 5e+007), (28.0, 5.1e+007)

Profit(t) = Profit(t - dt) + (Change_Profit) * dtINIT Profit = 0

INFLOWS:

Change_Profit = Incomes-Total_cost

Profit_BFarmer(t) = Profit_BFarmer(t - dt) + (Change_Profi_BFarmer) * dtINIT Profit_BFarmer = 0

INFLOWS:

Change_Profi_BFarmer = Incomes_Bfarmer-Total_cost_BFarmer

Profit_Mfarmer(t) = Profit_Mfarmer(t - dt) + (Change_Profit_MFarmer) * dtINIT Profit_Mfarmer = 0

INFLOWS:

Change_Profit_MFarmer = Incomes_Mfarmer-Total_Cost_MFarmer

Profit_Sfarmer(t) = Profit_Sfarmer(t - dt) + (Change_profit_Sfarmer) * dtINIT Profit_Sfarmer = 0

INFLOWS:

Change_profit_Sfarmer = Incomes_Sfarmer-Total_Cost_SFarmer

Approach_logistics_cost_x_ton = 70943

Cost_farmer_ton = Total_cost/(Supply*Conv_year)

Cost_Ha_Medium__Big_Farmer = 6974758

Cost_Ha__Small_Farmer = 6501689

Cost_Ton_BFarmer = Cost_Ha_Medium__Big_Farmer/Total_yield_BFarmer

Cost_Ton_MFarmer = Cost_Ha_Medium__Big_Farmer/Total_yield__MFarmer

Cost_Ton_SFarmer = Cost_Ha__Small_Farmer/Total_yield_SFarmer

Incomes = (Supply*Conv_year)*Price__farmer_ton

Incomes_Bfarmer = Participation_production_BF*Incomes

Incomes_Mfarmer = Participation___production_MF*Incomes

Incomes_Sfarmer = Participation__production_SF*Incomes

Logistics_cost_Mfarmer = Approach_logistics_cost_x_ton*Harvest_year_MFarmer

Logistics_cost_SFarmer = Approach_logistics_cost_x_ton*Harvest_Year_SFarmer

Logistic_cost_BFarmer = Approach_logistics_cost_x_ton*Harvest_year_BFarmer

Logistic_cost_No_Collaborative = Supply*Conv_year*Approach_logistics_cost_x_ton

Logistic_cost_vs_revenues = if(Incomes=0) then 0 else Total__logistic_cost/Incomes

Logistic_cost_vs_revenues_BFarmer = if(Incomes_Bfarmer=0) then 0 else Logistic_cost_BFarmer/Incomes_Bfarmer

Logistic_cost_vs_revenues_MFarmer = if(Incomes_Mfarmer=0) then 0 else Logistics_cost_Mfarmer/Incomes_Mfarmer

Logistic_cost_vs_revenues_Sfarmer = if(Incomes_Sfarmer=0) then 0 else Logistics_cost_SFarmer/Incomes_Sfarmer

Logistic_cost_vs_total_cost_Bfarmer = Logistic_cost_BFarmer/Total_cost_BFarmer

Logistic_cost_vs_total_cost_Mfarmer = Logistics_cost_Mfarmer/Total_Cost_MFarmer

Losgistic_cost_vs_Total__cost_SFarmer = Logistics_cost_SFarmer/Total_Cost_SFarmer

Margin_gross = if(Incomes=0) then 0 else (Incomes-Total_cost)/Incomes

Margin_gross_BFarmer = if(Incomes_Bfarmer=0) then 0 else (Incomes_Bfarmer-Total_cost_BFarmer)/Incomes_Bfarmer

Margin_gross_MFarmer = if(Incomes_Mfarmer=0) then 0 else (Incomes_Mfarmer-Total_Cost_MFarmer)/Incomes_Mfarmer

Margin_gross_SFarmer = if(Incomes_Sfarmer=0) then 0 else (Incomes_Sfarmer-Total_Cost_SFarmer)/Incomes_Sfarmer

No_collaborative_logistics_cost% = If(Incomes=0) then 1 else Logistic_cost_No_Collaborative/Incomes

Production_cost__total__x_Ton = 303137

Total_cost = Total_cost_BFarmer+Total_Cost_MFarmer+Total_Cost_SFarmer

Total_cost_BFarmer = Cost_Ton_BFarmer*Harvest_year_BFarmer

Total_Cost_MFarmer = Cost_Ton_MFarmer*Harvest_year_MFarmer

Total_Cost_SFarmer = Cost_Ton_SFarmer*Harvest_Year_SFarmer

Total_logistic_cost_vs_total_cost = Total__logistic_cost/Total_cost

Total__logistic_cost = Logistics_cost_Mfarmer+Logistics_cost_SFarmer+Logistic_cost_BFarmer

Comsuption_accum(t) = Comsuption_accum(t - dt) + (Harvest_for__comsuption_SF + Harvest_for__comsuption_MF + Harvest__for_consumption_BF) * dtINIT Comsuption_accum = 0

INFLOWS:

Harvest_for__comsuption_SF = Sowing__process_SFarmer*Potato__self_comsuption*Conv_year

Harvest_for__comsuption_MF = Sowing___proccess_MFarmer*Potato__self_comsuption*Conv_year

Harvest__for_consumption_BF = Sowing_proccess_BFarmer*Potato__self_comsuption*Conv_year

Seed_accum(t) = Seed_accum(t - dt) + (Harvest__for_seed_Sfarmer + Harvest_for_seed_MF + Harvest_for_seed_BF) * dtINIT Seed_accum = 0

INFLOWS:

Harvest__for_seed_Sfarmer = Sowing__process_SFarmer*Seed_share*Conv_year

Harvest_for_seed_MF = Sowing___proccess_MFarmer*Seed_share*Conv_year

Harvest_for_seed_BF = Sowing_proccess_BFarmer*Seed_share*Conv_year

Sowing_Ha_Big(t) = Sowing_Ha_Big(t - dt) + (Current_Ha_Big - Last_Ha_Big) * dtINIT Sowing_Ha_Big = Sowing_Ha_Init_Big

INFLOWS:

Current_Ha_Big = If(TIME>=25) then if(Post_conflict__growth_per_year=1) then (Sowing_Ha_Big*Effect_last__Price_on_Ha_cultivation*Conv_year*(1+Effect_post__conflict_per_year)) else (Sowing_Ha_Big*Effect_last__Price_on_Ha_cultivation*Conv_year) else (Sowing_Ha_Big*Effect_last__Price_on_Ha_cultivation*Conv_year)

OUTFLOWS:

Last_Ha_Big = Sowing_Ha_Big*Conv_year

Sowing_Ha_Medium(t) = Sowing_Ha_Medium(t - dt) + (Current_Ha_Med - Last_Ha_Med) * dtINIT Sowing_Ha_Medium = Sowing_Ha__Init_Medium

INFLOWS:

Current_Ha_Med = If(TIME>=25) then if(Post_conflict__growth_per_year=1) then (Sowing_Ha_Medium*Effect_last__Price_on_Ha_cultivation*Conv_year*(1+Effect_post__conflict_per_year)) else (Sowing_Ha_Medium*Effect_last__Price_on_Ha_cultivation*Conv_year) else (Sowing_Ha_Medium*Effect_last__Price_on_Ha_cultivation*Conv_year)

OUTFLOWS:

Last_Ha_Med = Sowing_Ha_Medium*Conv_year

Sowing_Ha_Small(t) = Sowing_Ha_Small(t - dt) + (Current_Ha - Last_Ha) * dtINIT Sowing_Ha_Small = Sowing_Ha_Init_Small

INFLOWS:

Current_Ha = If(TIME>=25) then if(Post_conflict__growth_per_year=1) then (Sowing_Ha_Small*Effect_last__Price_on_Ha_cultivation*Conv_year*(1+Effect_post__conflict_per_year)) else (Sowing_Ha_Small*Effect_last__Price_on_Ha_cultivation*Conv_year) else(Sowing_Ha_Small*Effect_last__Price_on_Ha_cultivation*Conv_year)

OUTFLOWS:

Last_Ha = Sowing_Ha_Small*Conv_year

Sowing_proccess_BFarmer(t) = Sowing_proccess_BFarmer(t - dt) + (Sowing_Year_BFarmer - Harvest_year_BFarmer - Harvest_for_seed_BF - Harvest__for_consumption_BF) * dtINIT Sowing_proccess_BFarmer = 762000

INFLOWS:

Sowing_Year_BFarmer = if(Change_climate_B2=1) then yield_bf*Ha_BFarmer*(1-(B2))*Effect_margin_over_investment_BFarmer else if(Change_climate_A2=1) THEN yield_bf*Ha_BFarmer*(1-(A2))*Effect_margin_over_investment_BFarmer ELSE yield_bf*Ha_BFarmer*Effect_margin_over_investment_BFarmer

OUTFLOWS:

Harvest_year_BFarmer = (Sowing_proccess_BFarmer*Production_to_market)*Conv_year

Harvest_for_seed_BF = Sowing_proccess_BFarmer*Seed_share*Conv_year

Harvest__for_consumption_BF = Sowing_proccess_BFarmer*Potato__self_comsuption*Conv_year

Sowing__process_SFarmer(t) = Sowing__process_SFarmer(t - dt) + (Sowing_Year_SFarmer - Harvest_for__comsuption_SF - Harvest_Year_SFarmer - Harvest__for_seed_Sfarmer) * dtINIT Sowing__process_SFarmer = 1844000

INFLOWS:

Sowing_Year_SFarmer = if(Change_climate_B2=1) then Yield_post_sf*Ha_SFarmer*(1-(B2))*Effect_margin__over_investment_SFarmer else if(Change_climate_A2=1) THEN Yield_post_sf*Ha_SFarmer*(1-(A2))*Effect_margin__over_investment_SFarmer ELSE Ha_SFarmer*Yield_post_sf*Effect_margin__over_investment_SFarmer

OUTFLOWS:

Harvest_for__comsuption_SF = Sowing__process_SFarmer*Potato__self_comsuption*Conv_year

Harvest_Year_SFarmer = (Sowing__process_SFarmer*Production_to_market)*Conv_year

Harvest__for_seed_Sfarmer = Sowing__process_SFarmer*Seed_share*Conv_year

Sowing___proccess_MFarmer(t) = Sowing___proccess_MFarmer(t - dt) + (Sowing_Year_M_Farmer - Harvest_for__comsuption_MF - Harvest_for_seed_MF - Harvest_year_MFarmer) * dtINIT Sowing___proccess_MFarmer = 857000

INFLOWS:

Sowing_Year_M_Farmer = if(Change_climate_B2=1) then Yield_post_mf*Ha_MFarmer*(1-(B2))*Effect_margin_over_investent_MFarmer else if(Change_climate_A2=1) THEN Yield_post_mf*Ha_MFarmer*(1-(A2))*Effect_margin_over_investent_MFarmer ELSE Yield_post_mf*Ha_MFarmer*Effect_margin_over_investent_MFarmer

OUTFLOWS:

Harvest_for__comsuption_MF = Sowing___proccess_MFarmer*Potato__self_comsuption*Conv_year

Harvest_for_seed_MF = Sowing___proccess_MFarmer*Seed_share*Conv_year

Harvest_year_MFarmer = (Sowing___proccess_MFarmer*Production_to_market)*Conv_year

Change_climate_A2 = 1

Change_climate_B2 = 1

Consumption_apparent = Harvest_for__comsuption_SF+Harvest_Year_SFarmer

Conv_year = 1

Effect_margin_over_investent_MFarmer = if(Margin_gross_MFarmer>Expected_margin_medium) then 1.05 else 1

Effect_margin_over_investment_BFarmer = if(Margin_gross_BFarmer>Expected_margin_Big) then 1.05 else 1

Effect_margin__over_investment_SFarmer = if(Margin_gross_SFarmer>Expected_margin_Small) then 1.05 else 1

Expected_margin_Big = 0.2

Expected_margin_medium = 0.2

Expected_margin_Small = 0.2

Gap_price = if(Last_Price=0) then 0 else (Current_Price-Last_Price)/Last_Price

Ha_BFarmer = Sowing_Ha_Big*Conv_year

Ha_MFarmer = Sowing_Ha_Medium*Conv_year

Ha_SFarmer = Sowing_Ha_Small*Conv_year

Post_conflict__growth_mean = 1

Post_conflict__growth_per_year = 1

Potato__self_comsuption = 0.07

Production_to_market = 0.89

Seed_share = 0.04

Sowing_Ha_Init_Big = 36630

Sowing_Ha_Init_Small = 103970

Sowing_Ha__Init_Medium = 44400

Total_sowing_Ha = Sowing_Ha_Big+Sowing_Ha_Medium+Sowing_Ha_Small

Total_yield = Harvest_year/Total_sowing_Ha

Total_yield_BFarmer = (Harvest_year_BFarmer+Harvest_for_seed_BF+Harvest__for_consumption_BF)/Ha_BFarmer

Total_yield_SFarmer = (Harvest_Year_SFarmer+Harvest_for__comsuption_SF+Harvest__for_seed_Sfarmer)/Ha_SFarmer

Total_yield__MFarmer = (Harvest_year_MFarmer+Harvest_for_seed_MF+Harvest_for__comsuption_MF)/Ha_MFarmer

yield_bf = if(Post_conflict__growth_mean=1) then Yield_big*(1+Effect_p_os_conf_mean) else Yield_big

Yield_big = 20.93

Yield_md = 19.32

Yield_post_mf = if(Post_conflict__growth_mean=1) then Yield_md*(1+Effect_p_os_conf_mean) else Yield_md

Yield_post_sf = if(Post_conflict__growth_mean=1) then Yield_sm*(1+Effect_p_os_conf_mean) else Yield_sm

Yield_sm = 17.74

A2 = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.0149), (26.0, 0.015), (27.0, 0.015), (28.0, 0.0149)

B2 = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.027), (26.0, 0.0265), (27.0, 0.0265), (28.0, 0.0265)

Effect_last__Price_on_Ha_cultivation = GRAPH(Gap_price)

(-0.07, 0.95), (-0.015, 0.85), (0.04, 1.05), (0.095, 1.08), (0.15, 1.10)

Effect_post__conflict_per_year = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.079), (26.0, 0.079), (27.0, 0.079), (28.0, 0.039), (29.0, 0.039), (30.0, 0.041), (31.0, 0.041), (32.0, 0.041), (33.0, 0.041), (34.0, 0.041)

Effect_p_os_conf_mean = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.053), (26.0, 0.053), (27.0, 0.053), (28.0, 0.053), (29.0, 0.053), (30.0, 0.053), (31.0, 0.053), (32.0, 0.053), (33.0, 0.053), (34.0, 0.053)

Yield_Init__small_Grower = GRAPH(TIME)

(1.00, 14.8), (2.00, 14.7), (3.00, 14.6), (4.00, 15.1), (5.00, 15.3), (6.00, 15.3), (7.00, 15.4), (8.00, 14.6), (9.00, 15.3), (10.0, 12.1), (11.0, 13.6), (12.0, 14.8), (13.0, 15.6), (14.0, 15.0), (15.0, 14.4), (16.0, 15.1), (17.0, 15.8), (18.0, 16.6), (19.0, 17.4), (20.0, 16.3), (21.0, 16.4), (22.0, 17.2), (23.0, 17.6), (24.0, 19.0)

Yield_medium_Grower = GRAPH(TIME)

(1.00, 16.1), (2.00, 16.0), (3.00, 15.9), (4.00, 16.4), (5.00, 16.7), (6.00, 16.6), (7.00, 16.8), (8.00, 15.9), (9.00, 16.6), (10.0, 13.2), (11.0, 14.8), (12.0, 16.1), (13.0, 16.9), (14.0, 16.3), (15.0, 15.7), (16.0, 16.4), (17.0, 17.2), (18.0, 18.1), (19.0, 18.9), (20.0, 17.8), (21.0, 17.9), (22.0, 18.7), (23.0, 19.1), (24.0, 20.7)

Yield__Init_big_Grower = GRAPH(TIME)

(1.00, 17.5), (2.00, 17.4), (3.00, 17.3), (4.00, 17.8), (5.00, 18.1), (6.00, 18.0), (7.00, 18.2), (8.00, 17.3), (9.00, 18.0), (10.0, 14.3), (11.0, 16.1), (12.0, 17.5), (13.0, 18.4), (14.0, 17.7), (15.0, 17.0), (16.0, 17.8), (17.0, 18.6), (18.0, 19.6), (19.0, 20.5), (20.0, 19.3), (21.0, 19.4), (22.0, 20.3), (23.0, 20.7), (24.0, 22.4)

APPENDIX B (POTATO´S SECTOR MODEL WHIT POLICY)

Demand and price

Supply(t) = Supply(t - dt) + (Harvest_Year_SFarmer + Harvest_year_MFarmer + Harvest_year_BFarmer - Harvest_shipment_depedent_on__the_intermedary - Harvest_shipment_dependent_on_the_farmers) * dtINIT Supply = 2800000

INFLOWS:

Harvest_Year_SFarmer (IN SECTOR: Production)

Harvest_year_MFarmer (IN SECTOR: Production)

Harvest_year_BFarmer (IN SECTOR: Production)

OUTFLOWS:

Harvest_shipment_depedent_on__the_intermedary = Supply*Rate_depedent__intermedary

Harvest_shipment_dependent_on_the_farmers = Supply*Rate_dependent__on_the_farmers

Variation_Price(t) = Variation_Price(t - dt) + (Current_Price - Last_Price) * dtINIT Variation_Price = 661000

INFLOWS:

Current_Price = Price__farmer_ton*Con_Ton_year

OUTFLOWS:

Last_Price = Variation_Price*Conv_year

Accumulation_product_rate = (Harvest_Year_SFarmer+Harvest_year_MFarmer+Harvest_year_BFarmer)/Demand

Comsuption_percapita = 0.0641

Con_Ton_year = 1

Demand = Domestic_consumption

Domestic_consumption = Comsuption_percapita*Population

Expected_margin = 0.20

Expected_price_farmer = -Cost_farmer_ton/(-1+Expected_margin)

incentive_demand = if(Change_climate_A2=1) or (Change_climate_B2=1) then if(Price_base_market<Expected_price_farmer) then 1.05 else 1 else 1

Potencial_External__comsuption = 10000000

Price_base_market = 400000

Price__farmer_ton = if(Post_conflict__growth_mean=1) then Expected_price_farmer*Effect_intermed_post*Effect_on_price else Expected_price_farmer*Effect__intermedary*Effect_on_price

Rate_depedent__intermedary = Rate_harvest_in_warehouse*incentive_demand

Rate_dependent__on_the_farmers = 1-Rate_depedent__intermedary

Effect_intermed_post = GRAPH(Rate_depedent__intermedary)

(0.99, 0.98), (0.995, 0.98), (1.00, 0.9)

Effect_on_price = GRAPH(Accumulation_product_rate)

(0.15, 0.00), (0.23, 1.58), (0.31, 1.45), (0.39, 1.40), (0.47, 1.30), (0.55, 1.25), (0.63, 1.05), (0.71, 0.98), (0.79, 0.92), (0.87, 0.98), (0.95, 0.98)

Effect__intermedary = GRAPH(Rate_depedent__intermedary)

(0.99, 0.95), (0.995, 0.95), (1.00, 0.9)

Population = GRAPH(TIME)

(1.00, 3.6e+007), (2.00, 3.7e+007), (3.00, 3.7e+007), (4.00, 3.8e+007), (5.00, 3.9e+007), (6.00, 3.9e+007), (7.00, 4e+007), (8.00, 4e+007), (9.00, 4.1e+007), (10.0, 4.1e+007), (11.0, 4.2e+007), (12.0, 4.2e+007), (13.0, 4.3e+007), (14.0, 4.3e+007), (15.0, 4.4e+007), (16.0, 4.4e+007), (17.0, 4.5e+007), (18.0, 4.6e+007), (19.0, 4.6e+007), (20.0, 4.7e+007), (21.0, 4.7e+007), (22.0, 4.8e+007), (23.0, 4.8e+007), (24.0, 4.9e+007), (25.0, 4.9e+007), (26.0, 5e+007), (27.0, 5e+007), (28.0, 5.1e+007)

Profit(t) = Profit(t - dt) + (Change_Profit) * dtINIT Profit = 0

INFLOWS:

Change_Profit = Incomes-Total_cost

Profit_BFarmer(t) = Profit_BFarmer(t - dt) + (Change_Profi_BFarmer) * dtINIT Profit_BFarmer = 0

INFLOWS:

Change_Profi_BFarmer = Revenues_Bfarmer-Total_cost_BFarmer

Profit_Mfarmer(t) = Profit_Mfarmer(t - dt) + (Change_Profit_MFarmer) * dtINIT Profit_Mfarmer = 0

INFLOWS:

Change_Profit_MFarmer = Revenues_Mfarmer-Total_Cost_MFarmer

Profit_Sfarmer(t) = Profit_Sfarmer(t - dt) + (Change_profit_Sfarmer) * dtINIT Profit_Sfarmer = 0

INFLOWS:

Change_profit_Sfarmer = Revenues_Sfarmer-Total_Cost_SFarmer

Approach_logistics_cost_x_ton = 70943

Contribution_SFarmer = if(Revenues_Sfarmer=0) then 0 else (Revenues_Sfarmer-Total_Cost_SFarmer)/Revenues_Sfarmer

Cost_col = if(Synergies_rate>1) then Harvest_Year_SFarmer*Cost_collaborative__per_ton else Cost_collaborative__per_ton*Harvest_Year_SFarmer*Synergies_rate

Cost_col_b = if(Synergies_rate>1) then (1-(Synergies_rate/2))*Cost_collaborative__per_ton*Harvest_year_BFarmer else 0

Cost_col_m = if(Synergies_rate>1) then (1-(Synergies_rate/2))*Cost_collaborative__per_ton*Harvest_year_MFarmer else 0

Cost_farmer_ton = Total_cost/(Supply*Conv_year)

Cost_Ha_Medium__Big_Farmer = if(Synergies_rate>1) then 6974758*0.9 else 6974758

Cost_Ha__Small_Farmer = if(Synergies_rate>0) then 6501689*0.85 else 6501689

Cost_Ton_BFarmer = Cost_Ha_Medium__Big_Farmer/Total_yield_BFarmer

Cost_Ton_MFarmer = Cost_Ha_Medium__Big_Farmer/Total_yield__MFarmer

Cost_Ton_SFarmer = Cost_Ha__Small_Farmer/Total_yield_SFarmer

Gross_margin = if(Incomes=0) then 0 else (Incomes-Total_cost)/Incomes

Incomes = (Supply*Conv_year)*Price__farmer_ton

Logistics_cost_Mfarmer = Approach_logistics_cost_x_ton*Harvest_year_MFarmer

Logistics_cost_SFarmer = Approach_logistics_cost_x_ton*Harvest_Year_SFarmer

Logistic_cost_BFarmer = Approach_logistics_cost_x_ton*Harvest_year_BFarmer

Logistic_cost_No_Collaborative = Supply*Conv_year*Approach_logistics_cost_x_ton

Logistic_cost_vs_revenues = if(Incomes=0) then 0 else Total__logistic_cost/Incomes

Logistic_cost_vs_revenues_BFarmer = if(Revenues_Bfarmer=0) then 0 else Logistic_cost_BFarmer/Revenues_Bfarmer

Logistic_cost_vs_revenues_MFarmer = if(Revenues_Mfarmer=0) then 0 else Logistics_cost_Mfarmer/Revenues_Mfarmer

Logistic_cost_vs_revenues_Sfarmer = if(Revenues_Sfarmer=0) then 0 else Logistics_cost_SFarmer/Revenues_Sfarmer

Logistic_cost_vs_total_cost_Bfarmer = Logistic_cost_BFarmer/Total_cost_BFarmer

Logistic_cost_vs_total_cost_Mfarmer = Logistics_cost_Mfarmer/Total_Cost_MFarmer

Losgistic_cost_vs_Total__cost_SFarmer = Logistics_cost_SFarmer/Total_Cost_SFarmer

Margin_gross_BFarmer = if(Revenues_Bfarmer=0) then 0 else (Revenues_Bfarmer-Total_cost_BFarmer)/Revenues_Bfarmer

Margin_gross_MFarmer = if(Revenues_Mfarmer=0) then 0 else (Revenues_Mfarmer-Total_Cost_MFarmer)/Revenues_Mfarmer

No_collaborative_logistics_cost% = If(Incomes=0) then 1 else Logistic_cost_No_Collaborative/Incomes

Production_cost__total__x_Ton = 303137

Revenues_Bfarmer = Participation_production_BF*Incomes

Revenues_Mfarmer = Participation___production_MF*Incomes

Revenues_Sfarmer = Participation__production_SF*Incomes

Total_cost = Total_cost_BFarmer+Total_Cost_MFarmer+Total_Cost_SFarmer

Total_cost_BFarmer = (Cost_Ton_BFarmer*Harvest_year_BFarmer)+Cost_col_b

Total_Cost_MFarmer = (Cost_Ton_MFarmer*Harvest_year_MFarmer)+Cost_col_m

Total_Cost_SFarmer = (Cost_Ton_SFarmer*Harvest_Year_SFarmer)+Cost_col

Total_logistic_cost_vs_total_cost = Total__logistic_cost/Total_cost

Total__logistic_cost = Logistics_cost_Mfarmer+Logistics_cost_SFarmer+Logistic_cost_BFarmer

Comsuption_accum(t) = Comsuption_accum(t - dt) + (Harvest_for__comsuption_SF + Harvest_for__comsuption_MF + Harvest__for_consumption_BF) * dtINIT Comsuption_accum = 0

INFLOWS:

Harvest_for__comsuption_SF = Sowing__process_SFarmer*Potato__self_comsuption*Conv_year

Harvest_for__comsuption_MF = Sowing_proccess_MFarmer*Potato__self_comsuption*Conv_year

Harvest__for_consumption_BF = Sowing_proccess_BFarmer*Potato__self_comsuption*Conv_year

Idle_capacity(t) = Idle_capacity(t - dt) + (Available_capacity - Used_capacity) * dtINIT Idle_capacity = 0

INFLOWS:

Available_capacity = Logistic_Infra*mt3_year

OUTFLOWS:

Used_capacity = if(Req_m3_store>0) then min(Req_m3_store/Conv_year,Available_capacity) else 0

Logistic_Infra(t) = Logistic_Infra(t - dt) + (Change_infra_warehouse_mt3 - Return_infra_warehouse_mt3) * dtINIT Logistic_Infra = 10000

INFLOWS:

Change_infra_warehouse_mt3 = if(Req_m3_store>Logistic_Infra) then if((Req_m3_store-Logistic_Infra)<Size_modul) then Size_modul/Conv_year else ((Req_m3_store-Logistic_Infra)/Time_development_infra) else 0

OUTFLOWS:

Return_infra_warehouse_mt3 = if(time=Agreement_time_APP) then if(Iddle_capacity_year>Size_modul/Conv_year)then Iddle_capacity_year else 0 else 0

loss_store(t) = loss_store(t - dt) + (Harvest_store_year - Harvest_store_shipment) * dtINIT loss_store = 0

INFLOWS:

Harvest_store_year = Capacity_Tons_Warehouse

OUTFLOWS:

Harvest_store_shipment = loss_store*Conv_year*(1-Avg_loss_store)

Seed_accum(t) = Seed_accum(t - dt) + (Harvest__for_seed_Sfarmer + Harvest_for_seed_MF + Harvest_for_seed_BF) * dtINIT Seed_accum = 0

INFLOWS:

Harvest__for_seed_Sfarmer = Sowing__process_SFarmer*Seed_share*Conv_year

Harvest_for_seed_MF = Sowing_proccess_MFarmer*Seed_share*Conv_year

Harvest_for_seed_BF = Sowing_proccess_BFarmer*Seed_share*Conv_year

Sowing_Ha_Big(t) = Sowing_Ha_Big(t - dt) + (Current_Ha_Big - Last_Ha_Big) * dtINIT Sowing_Ha_Big = Sowing_Ha_Init_Big

INFLOWS:

Current_Ha_Big = Sowing_Ha_Big*Effect_last__Price_on_Ha_cultivation*Conv_year

OUTFLOWS:

Last_Ha_Big = Sowing_Ha_Big*Conv_year

Sowing_Ha_Medium(t) = Sowing_Ha_Medium(t - dt) + (Current_Ha_Med - Last_Ha_Med) * dtINIT Sowing_Ha_Medium = Sowing_Ha__Init_Medium

INFLOWS:

Current_Ha_Med = Sowing_Ha_Medium*Effect_last__Price_on_Ha_cultivation*Conv_year

OUTFLOWS:

Last_Ha_Med = Sowing_Ha_Medium*Conv_year

Sowing_Ha_Small(t) = Sowing_Ha_Small(t - dt) + (Current_Ha - Last_Ha) * dtINIT Sowing_Ha_Small = Sowing_Ha_Init_Small

INFLOWS:

Current_Ha = Sowing_Ha_Small*Effect_last__Price_on_Ha_cultivation*Conv_year

OUTFLOWS:

Last_Ha = Sowing_Ha_Small*Conv_year

Sowing_proccess_BFarmer(t) = Sowing_proccess_BFarmer(t - dt) + (Sowing_Year_BFarmer - Harvest_year_BFarmer - Harvest_for_seed_BF - Harvest__for_consumption_BF) * dtINIT Sowing_proccess_BFarmer = 762000

INFLOWS:

Sowing_Year_BFarmer = if(Change_climate_B2=1) then yield_bf*Ha_BFarmer*(1-(B2))*Effect_margin_over_investment__BFarmer else if(Change_climate_A2=1) THEN yield_bf*Ha_BFarmer*(1-(A2))*Effect_margin_over_investment__BFarmer ELSE yield_bf*Ha_BFarmer*Effect_margin_over_investment__BFarmer

OUTFLOWS:

Harvest_year_BFarmer = (Sowing_proccess_BFarmer*Production_to_market)*Conv_year

Harvest_for_seed_BF = Sowing_proccess_BFarmer*Seed_share*Conv_year

Harvest__for_consumption_BF = Sowing_proccess_BFarmer*Potato__self_comsuption*Conv_year

Sowing_proccess_MFarmer(t) = Sowing_proccess_MFarmer(t - dt) + (Sowing_Year_M_Farmer - Harvest_for__comsuption_MF - Harvest_for_seed_MF - Harvest_year_MFarmer) * dtINIT Sowing_proccess_MFarmer = 857000

INFLOWS:

Sowing_Year_M_Farmer = if(Change_climate_B2=1) then Yield_post_mf*Ha_MFarmer*(1-(B2))*Effect_margin_over_Invesment else if(Change_climate_A2=1) THEN Yield_post_mf*Ha_MFarmer*(1-(A2))*Effect_margin_over_Invesment ELSE Yield_post_mf*Ha_MFarmer*Effect_margin_over_Invesment

OUTFLOWS:

Harvest_for__comsuption_MF = Sowing_proccess_MFarmer*Potato__self_comsuption*Conv_year

Harvest_for_seed_MF = Sowing_proccess_MFarmer*Seed_share*Conv_year

Harvest_year_MFarmer = (Sowing_proccess_MFarmer*Production_to_market)*Conv_year

Sowing__process_SFarmer(t) = Sowing__process_SFarmer(t - dt) + (Sowing_Year_SFarmer - Harvest_for__comsuption_SF - Harvest_Year_SFarmer - Harvest__for_seed_Sfarmer) * dtINIT Sowing__process_SFarmer = 1844000

INFLOWS:

Sowing_Year_SFarmer = if(Change_climate_B2=1) then Yield_post_sf*Ha_SFarmer*(1-(B2))*Effect_margin__over_invesment_SFarmer else if(Change_climate_A2=1) THEN Yield_post_sf*Ha_SFarmer*(1-(A2))*Effect_margin__over_invesment_SFarmer ELSE Ha_SFarmer*Yield_post_sf*Effect_margin__over_invesment_SFarmer

OUTFLOWS:

Harvest_for__comsuption_SF = Sowing__process_SFarmer*Potato__self_comsuption*Conv_year

Harvest_Year_SFarmer = (Sowing__process_SFarmer*Production_to_market)*Conv_year

Harvest__for_seed_Sfarmer = Sowing__process_SFarmer*Seed_share*Conv_year

Agreement_time_APP = 15

Average__yield_per_UPA = 52

Avg_loss_store = 0.0563

Capacity_Tons_Warehouse = Used_capacity*Tons_per_m3

Change_climate_A2 = 1

Change_climate_B2 = 1

Consumption_apparent = Harvest_for__comsuption_SF+Harvest_Year_SFarmer

Convert_tons_to_m3 = 2

Conv_year = 1

Cost_Collaborative_year = Logistic_Infra*Cost_m3

Cost_collaborative__per_ton = Cost_Collaborative_year*Conv_year/Harvest_store_year

Effect_margin_over_Invesment = if(Margin_gross_MFarmer>Expected_margin_medium) then 1.05 else 1

Effect_margin_over_investment__BFarmer = if(Margin_gross_BFarmer>Expected_margin_Big) then 1.05 else 1

Effect_margin__over_invesment_SFarmer = if(Contribution_SFarmer>Expected_margin_Small) then 1.05 else 1

Encourage = 0.3

Expected_margin_Big = 0.2

Expected_margin_medium = 0.2

Expected_margin_Small = 0.2

Gap_price = if(Last_Price=0) then 0 else (Current_Price-Last_Price)/Last_Price

Harvest_year = Harvest_year_BFarmer+Harvest_year_MFarmer+Harvest_Year_SFarmer

Ha_BFarmer = Sowing_Ha_Big*Conv_year

Ha_MFarmer = Sowing_Ha_Medium*Conv_year

Ha_SFarmer = Sowing_Ha_Small*Conv_year

Iddle_capacity_year = if(Used_capacity>Available_capacity) then Available_capacity else Available_capacity-Used_capacity

mt3_year = 1

Participation_production_BF = Harvest_year_BFarmer/Harvest_year

Participation__production_SF = Harvest_Year_SFarmer/Harvest_year

Participation___production_MF = Harvest_year_MFarmer/Harvest_year

Post_conflict__growth_mean = 1

Potato__self_comsuption = 0.07

Production_to_market = 0.89

Rate_harvest_in_warehouse = Harvest_store_year/(Supply*Conv_year)

Rate_harvest_small = Harvest_Year_SFarmer/Harvest_store_year

Req_m3_store = Convert_tons_to_m3*Supply*Encouragement

Seed_share = 0.04

Size_modul = 37500

Sowing_Ha_Init_Big = 36630

Sowing_Ha_Init_Small = 103970

Sowing_Ha__Init_Medium = 44400

Synergies_rate = if(Harvest_store_year=0) then 0 else Harvest_store_year/Harvest_Year_SFarmer

Time_development_infra = 2

Tons_per_m3 = 0.5

Total_sowing_Ha = Sowing_Ha_Big+Sowing_Ha_Medium+Sowing_Ha_Small

Total_yield = Harvest_year/Total_sowing_Ha

Total_yield_BFarmer = (Harvest_year_BFarmer+Harvest_for_seed_BF+Harvest__for_consumption_BF)/Ha_BFarmer

Total_yield_SFarmer = (Harvest_Year_SFarmer+Harvest_for__comsuption_SF+Harvest__for_seed_Sfarmer)/Ha_SFarmer

Total_yield__MFarmer = (Harvest_year_MFarmer+Harvest_for_seed_MF+Harvest_for__comsuption_MF)/Ha_MFarmer

Utilization_capacity = If(Available_capacity=0) then 0 else Used_capacity/Available_capacity

yield_bf = if(Post_conflict__growth_mean=1) then Yield_big*(1+Effect_p_os_conf_mean) else Yield_big

Yield_big = 20.93

Yield_md = 19.32

Yield_post_mf = if(Post_conflict__growth_mean=1) then Yield_md*(1+Effect_p_os_conf_mean) else Yield_md

Yield_post_sf = if(Post_conflict__growth_mean=1) then Yield_sm*(1+Effect_p_os_conf_mean) else Yield_sm

Yield_sm = 17.74

A2 = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.0149), (26.0, 0.015), (27.0, 0.015), (28.0, 0.0149)

B2 = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.027), (26.0, 0.0265), (27.0, 0.0265), (28.0, 0.0265)

Cost_m3 = GRAPH(Agreement_time_APP)

(5.00, 32000), (10.0, 25600), (15.0, 16000)

Effect_last__Price_on_Ha_cultivation = GRAPH(Gap_price)

(-0.07, 0.95), (-0.015, 0.85), (0.04, 1.05), (0.095, 1.08), (0.15, 1.10)

Effect_p_os_conf_mean = GRAPH(TIME)

(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.053), (26.0, 0.053), (27.0, 0.053), (28.0, 0.053), (29.0, 0.053), (30.0, 0.053), (31.0, 0.053), (32.0, 0.053), (33.0, 0.053), (34.0, 0.053)

Yield_Init__small_Grower = GRAPH(TIME)

(1.00, 14.8), (2.00, 14.7), (3.00, 14.6), (4.00, 15.1), (5.00, 15.3), (6.00, 15.3), (7.00, 15.4), (8.00, 14.6), (9.00, 15.3), (10.0, 12.1), (11.0, 13.6), (12.0, 14.8), (13.0, 15.6), (14.0, 15.0), (15.0, 14.4), (16.0, 15.1), (17.0, 15.8), (18.0, 16.6), (19.0, 17.4), (20.0, 16.3), (21.0, 16.4), (22.0, 17.2), (23.0, 17.6), (24.0, 19.0)

Yield_medium_Grower = GRAPH(TIME)

(1.00, 16.1), (2.00, 16.0), (3.00, 15.9), (4.00, 16.4), (5.00, 16.7), (6.00, 16.6), (7.00, 16.8), (8.00, 15.9), (9.00, 16.6), (10.0, 13.2), (11.0, 14.8), (12.0, 16.1), (13.0, 16.9), (14.0, 16.3), (15.0, 15.7), (16.0, 16.4), (17.0, 17.2), (18.0, 18.1), (19.0, 18.9), (20.0, 17.8), (21.0, 17.9), (22.0, 18.7), (23.0, 19.1), (24.0, 20.7)

Yield__Init_big_Grower = GRAPH(TIME)

(1.00, 17.5), (2.00, 17.4), (3.00, 17.3), (4.00, 17.8), (5.00, 18.1), (6.00, 18.0), (7.00, 18.2), (8.00, 17.3), (9.00, 18.0), (10.0, 14.3), (11.0, 16.1), (12.0, 17.5), (13.0, 18.4), (14.0, 17.7), (15.0, 17.0), (16.0, 17.8), (17.0, 18.6), (18.0, 19.6), (19.0, 20.5), (20.0, 19.3), (21.0, 19.4), (22.0, 20.3), (23.0, 20.7), (24.0, 22.4)

APPENDIX C : (MODEL DEVELOPMENT AND CALIBRATION)

The design of the model using System Dynamics is carried out through four sectors that allow the evaluation of performance measures.

Production sector

The supply chain starts from the sowing process directly related to the cultivated hectares and their yield, which in turn is diminished by internal consumption, by the production used as seed and dependent on rainfall and climatic conditions in the area. On the other hand, the dynamic analysis allows to analyze the causality of the financial benefits obtained by the producer and the effect on the next crop, given the amount of hectares to be planted and the investment to be made. The size of the producer presents a concentration towards small and medium, where their yields vary, as well as the participation in the harvested lands. This behavior affects the production obtained, its investment capacity and its development.

In the "stock and flow" diagram we observe the state variables: cultivated hectares (HS), cultivated tons (TS), tons used as seed (TSS), crop dedicated to self-consumption (SC) and the change rates: current cultivated hectares (RHC), cultivated hectares from the previous period (RLH), rate of cultivated tons (RTS), rate of tons harvested per year (RTH), rate of crop dedicated as seed (RSS) and rate of crop used for self-consumption (RSC). The main equations are given by:

Hectares cultivated by each producer type *i* according to their size::

$$(1) \qquad HS_i\,(t) = HS_i(t-dt) + (RHC_i - RLH_i)dt \quad \forall = 1,2,3$$

Tons cultivated by each type *i* producer according to their size::

$$(2) \qquad TS_i\,(t) = TS_i\,(t-dt) + (RTS_i - \mathrm{RTH}_i - \mathrm{RSS}_i - \mathrm{RSC}_i)dt \quad \forall = 1,2,3$$

The change rate of the current cultivated hectares for each type *i* producer is given by: :

$$(3) \qquad RHC_i = \mathrm{HS}_i * \mathrm{ELP} * (1+\mathrm{EFP}) \quad \forall = 1,2,3$$

$$Where:$$

$$ELP: the\ effect\ of\ the\ last\ price\ received\ by\ the\ producer\ on\ the\ sowing\ decision.$$

$$EFP: effect\ of\ the\ post-conflict\ armed\ conflict\ on\ the\ sowing\ decision.$$

The change rate of the tons cultivated by each producer type *i* is given by:

$$(4) \qquad RTC_i = \mathrm{YL}_i * \mathrm{HS}_i * (1-\mathrm{ECC}) * \mathrm{EMI} \quad \forall = 1,2,3$$

Where:

YL_i: yield tonnes per hectare cultivated of producer type i

$ECC: effect\ of\ climate\ change\ on\ cultivation$

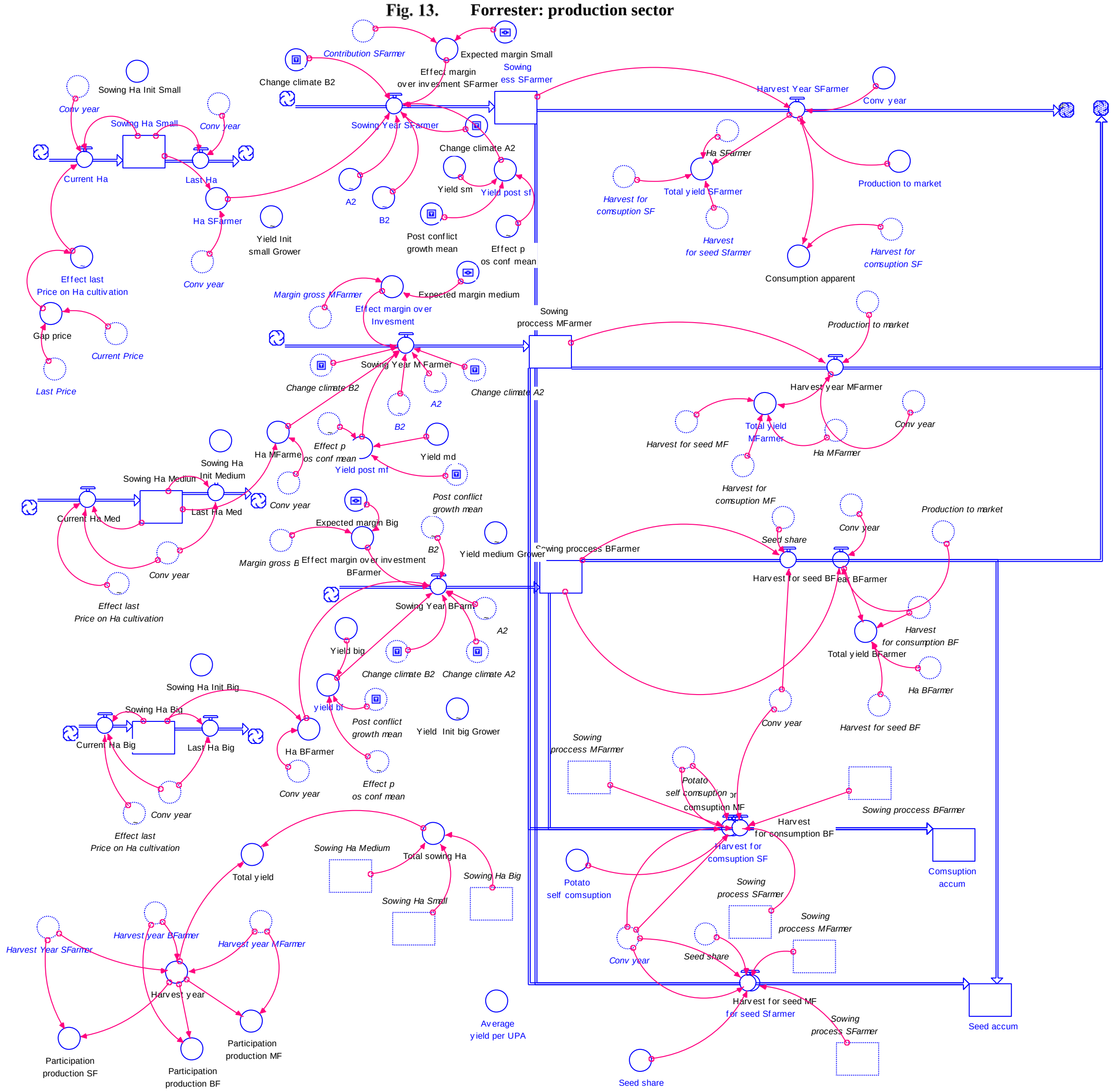
$EMI: the\ effect\ of\ the\ gross\ margin\ perceived\ by\ the\ producer\ on\ the\ investment\ in\ the\ crop$

$$(5) \qquad YL_i = \frac{(\mathrm{RTH}_i + \mathrm{RSS}_i + \mathrm{RSC}_i)}{HS_i} \quad \forall = 1,2,3$$

The change rate of the tons harvested by producer type *i*, is given by::

$$(6) \quad RTH_i = TS_i * \mathrm{PM} \quad \forall = 1,2,3$$
$$Where:$$
$$PM: Market - driven\ production\ share$$

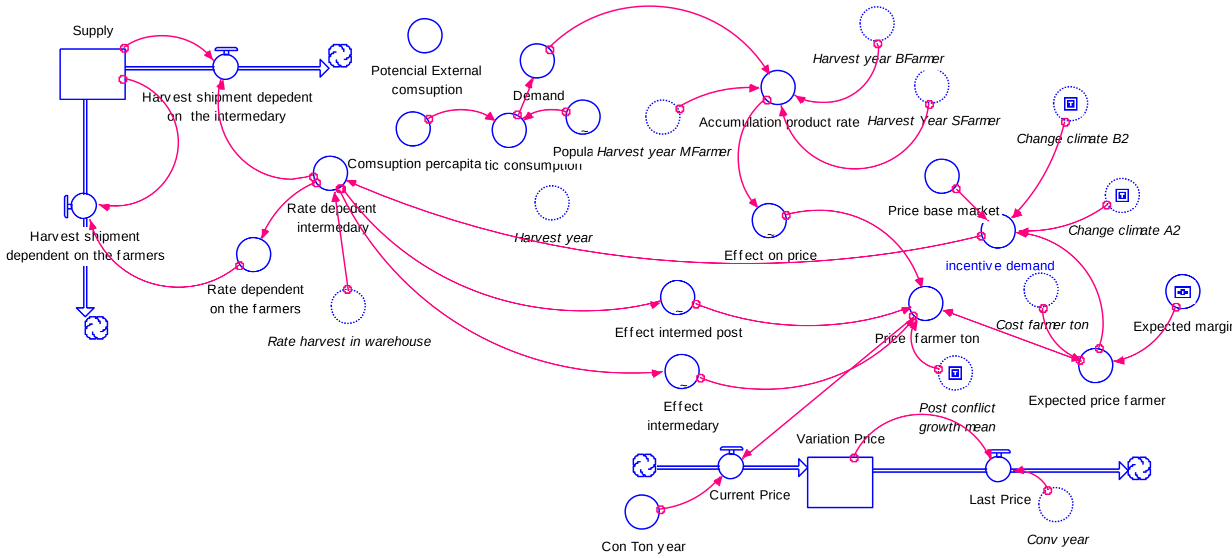
Fig. 13. Forrester: production sector



Market and Intermediation

The harvest obtained meets demand, whose projections are associated with population and average per capita consumption, as well as potential demand at the export level. The demand for potato is considered inelastic to the price, however, the price perceived by the producer is a variable dependent on aspects such as environmental rainfall, climate change and high intermediation during the marketing of the product, which together make the producer, despite being the basis of the chain, does not have a strong position in the definition of selling price, which affects the income of producers and their investment decision and scope of cultivation in each planting period.

Fig. 14. Forrester : market and intermediation



In this sector and according to the "stock and flow" diagram, the state variables are: product supply (SP) and price variation (PV) and change rates: crop change in the market through intermediaries (RHI), crop change in the market through the producer (RHF), price of the current period (RCP) and price of the previous period (RLP). Other significant variables in the sector are dependence on intermediation (DI), expected producer price (EPP), product accumulation (PA), domestic demand (D), price received by the producer (PP). The main equations of the sector are given by:

Product supply

$$(7) \qquad SP\ (t) = SP(t - dt) + (\textstyle\sum_{i=1}^{n} RTH_i - RHI - RHF)dt \quad donde\ i = 1,2,3$$

Variation in price:

$$(8) \qquad VP\ (t) = VP(t - dt) + (RCP - RLP)dt$$

Change of crop in the market through intermediaries

$$(9) \qquad RHI = \mathrm{SP} * \mathrm{IR}$$

$$Where$$

$$IR: Intermediation\ rate$$

Expected producer price:

$$(10) \qquad EPP = CTP * EGM$$

$$Where$$

$$CTP: Cost\ per\ tonne\ produced$$

$$EGM: Gross\ margin\ expected\ by\ the\ producer$$

Product Accumulation:

$$(11) \qquad PA = \sum_{i=1}^{n} RTH_i * D \quad where\ i = 1,2,3$$

Price charged for the productr:

$$(12) \qquad PPP = \text{EPP} * \text{EI} * \text{EAP}$$
$$Where$$
$$EI: effect\ of\ intermediation$$
$$EAP: effect\ of\ product\ accumulation$$

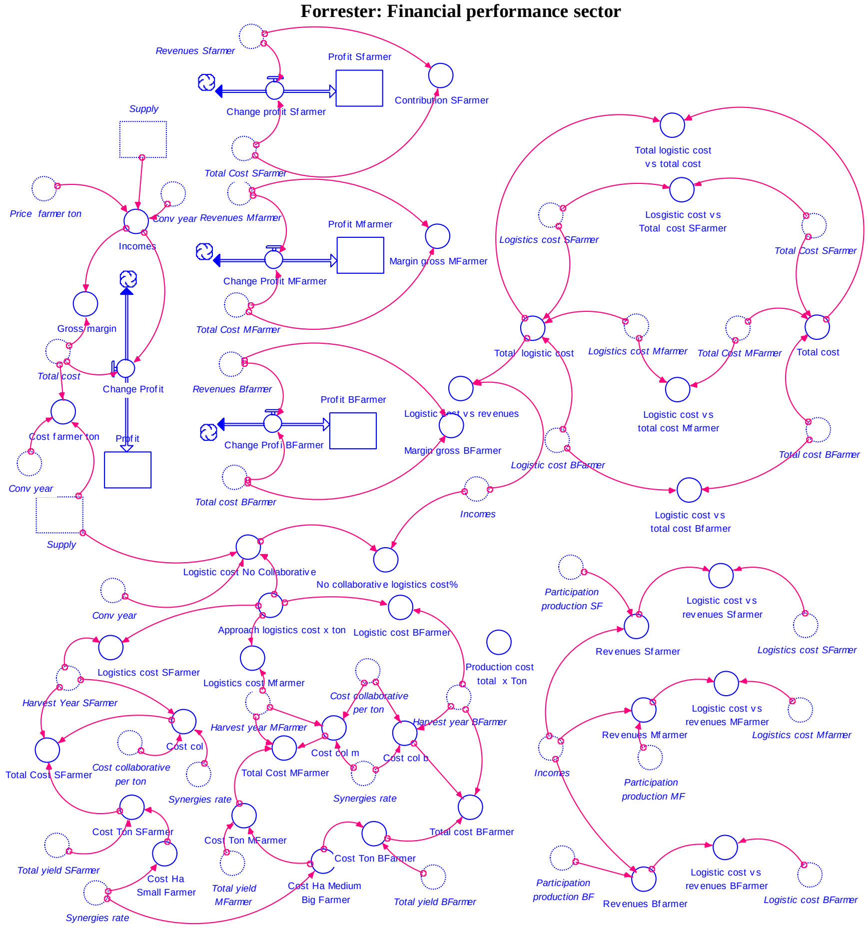
Domestic demand:

$$(13) \qquad D = \text{CPC} * \text{P}$$
$$Where$$
$$CPC: per\ capita\ consumption$$
$$P: population$$

Financial performance sector

Under current conditions, the producer is subject to the seasonal behavior of the offer and the conditions imposed mainly by the marketers. The analysis of the resulting variations in financial margins affect decisions on the next production cycle, such as the hectares to be planted and investments that largely define crop yields. On the other hand, the benefits obtained act on the size of the producer and affect his development and growth towards greater competitiveness.

Forrester: Financial performance sector



In the financial performance sector, there is the state variable total profits and by type of producer (PF) and the flow variables: change in perceived profits (RPF), other relevant variables are: cost per ton produced (CTP), total costs (TC), income (IC), gross margin (MG).

Total profits:

$$(14) \qquad PF\ (t) = PF(t - dt) + (RPF)dt$$

Profits for each type *i* producer:

$$(15) \qquad PF_i\ (t) = PF_i(t - dt) + (RPF_i)dt \quad \forall = 1{,}2{,}3$$

Change in total earnings received:

$$(16) \qquad RPF = \mathrm{IC} - \mathrm{TC}$$

Change in earnings received by each type *i* producer:

$$(17) \qquad RPF_i = \mathrm{IC}_i - \mathrm{TC}_i \quad \forall = 1{,}2{,}3$$

Cost per tonne for each type *i* producer:

$$(18) \qquad CTP_i = \frac{\mathrm{CH}_i}{YL_i} \quad \forall = 1{,}2{,}3$$

$$Where$$

$$CH_i: cost\ per\ hectare\ sown\ by\ type\ of\ producer\ i$$

Total costs

$$(19) \qquad TC = \sum_{i=1}^{n} TC_i \quad where\ i = 1{,}2{,}3$$

Total costs for each type *i* producer:

$$(20) \qquad TC_i = \mathrm{CTP}_i * RTH_i \quad \forall = 1{,}2{,}3$$

Total revenues

$$(21) \qquad \mathrm{IC} = SP * PPP$$

Total revenues for each type *i* producer::

$$(22) \qquad \mathrm{IC}_i = \mathrm{IC} * PKP_i \quad \forall = 1{,}2{,}3$$

$$where$$

$$PKP_i: share\ of\ production\ by\ type\ of\ producer\ i$$

Margins gross total

$$\mathrm{MG} = \frac{\mathrm{IC} - \mathrm{TC}}{\mathrm{IC}}$$

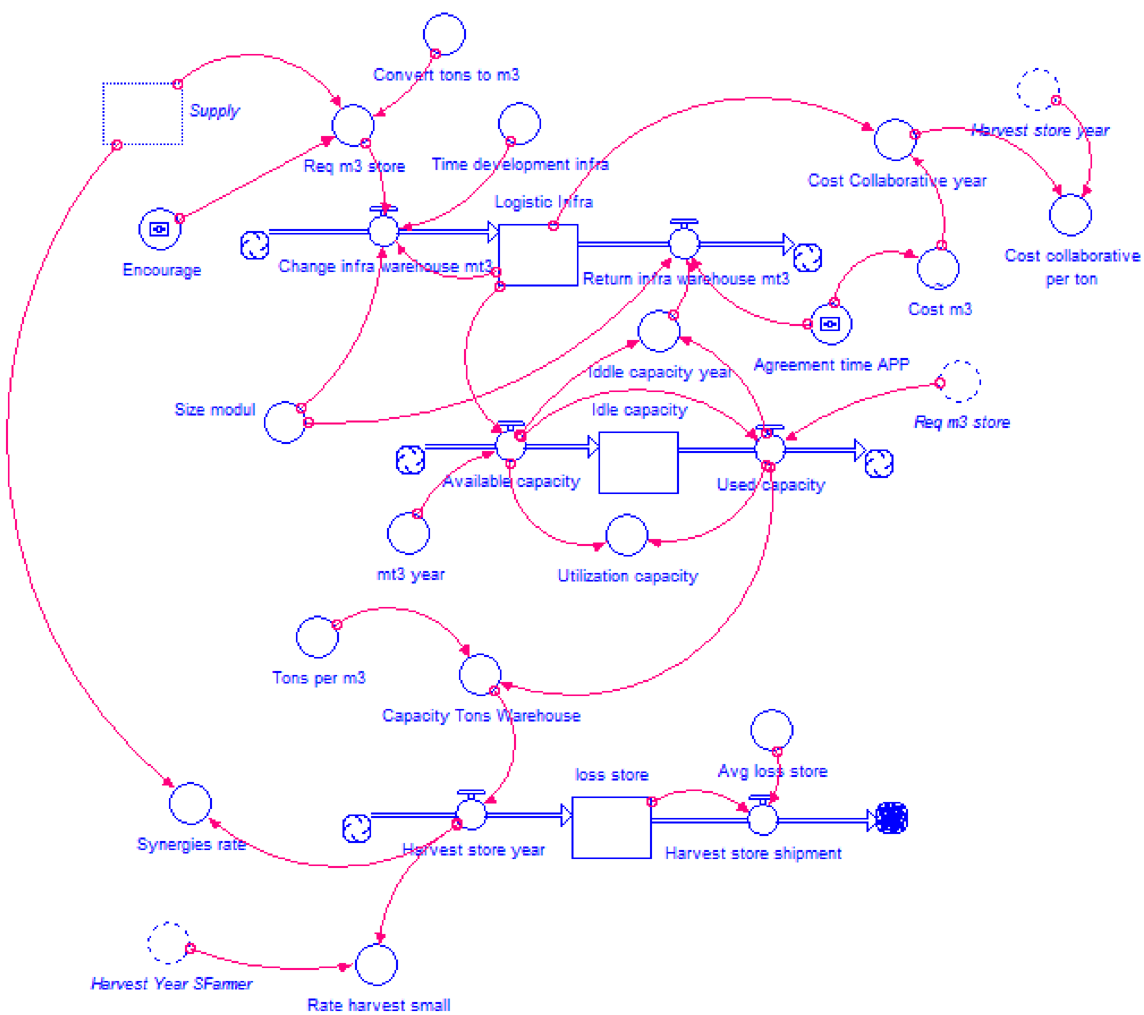
Gross margin for each type *i* producer:

$$MG_i = \frac{IC_i - TC_i}{IC_i} \qquad \forall = 1,2,3$$

Expansion of the production sector to include the structure of logistical collaboration.

Given the interest in proposing collaborative policies in distribution centers that allow producers to be associated and the implementation of strategies that balance supply and demand, the development of collaborative infrastructures for the storage and distribution of the harvest is considered. The sector considers the available capacity and the development of warehouses, the unused capacity, the associated agricultural production units, among others.

Expansion of the production sector to include the structure of logistical collaboration.



The expansion of the production sector, considering the inclusion of elements of collaborative public policy, has the following state variables: logistical infrastructure (WH), idle capacity (IDC), loss of stored crop (LS); the flow variables: change of new infrastructure (RNWH), return of infrastructure (RRWH) available capacity (RAC), used capacity (RUC), harvest received in the warehouse (RHS), stored and shipped harvest (RHSS).

Other relevant variables in the sector expansion are: synergy ratio (SR), storage cubic meter requirement (SMR), capacity utilization (UC). The main equations are:

Logistics infraestructure:

$$(23) \qquad WH\ (t) = WH(t-dt) + (RNWH - RRWH)dt$$

Iddle capacity

$$(24) \qquad IDC\ (t) = \mathrm{IDC}(t-dt) + (RAC - RUC)dt$$

Loss of stored crop::

$$(25) \qquad LS\ (t) = LS(t-dt) + (RHS - RRHS)dt$$

Change of new infrastructure:

$$(26) \qquad \mathrm{RNWH} = \begin{cases} \mathrm{SZM,\ (SMR>WH)} \wedge ((\mathrm{SMR\text{-}WH})<\mathrm{SZM}) \\ \frac{\mathrm{SMR\text{-}WH}}{\mathrm{TDWH}}, \mathrm{SMR>WH} \\ 0,\ \mathrm{otherwise} \end{cases}$$

$$Where$$
$$TDWH: time\ needed\ for\ infrastructure\ development$$
$$SZM: minimum\ size\ of\ the\ infrastructure\ module\ to\ be\ developed$$

Change due to return of infrastructure:

$$(27) \qquad RRWH = \begin{cases} IDC_t, \mathrm{time} \geq \mathrm{TPPP}\ \wedge IDC_t > SZM \\ 0, otherwise \end{cases}$$

$$Where$$
$$TPPP: agreement\ time\ of\ the\ public - private\ partnership$$
$$IDC_t: Idle\ capacity\ of\ period\ t$$

Change of available capacity:

$$(28) \qquad RAC = \mathrm{WH}$$

Escriba aquí la ecuación.

Change of capacity use:

$$(29) \qquad RUC = \begin{cases} \min(SMR, RAC), \mathrm{SMR} > 0 \\ 0, otherwise \end{cases}$$

Change of harvest received in the warehouse

$$(30) \qquad RHS = RUC * CCM$$

$$Where$$

$$CCM: conversion\ from\ cubic\ metres\ to\ tonnes$$

Change of stored crop

$$(31)\qquad RHSS = LS * (1 - RL)$$

$$Where$$

$$RL: Loss\ rate$$

Relationship of synergies achieved

$$(32)\qquad SR = \frac{\mathrm{RHS}}{\mathrm{SP}}$$

Requirement of cubic meters for storage

$$(33)\qquad SMR = \mathrm{SP} * \mathrm{CTCM} * \mathrm{ENC}$$

$$Where$$

$$ENC: Encourage, \quad level\ of\ encouragement\ by\ the\ State$$

$$CTCM: Equivalent\ of\ tons\ to\ cubic\ meters$$

Capacity utilization (UC)

$$(34)\qquad UC = \frac{\mathrm{RUC}}{\mathrm{RAC}}$$

MODEL CALIBRATION

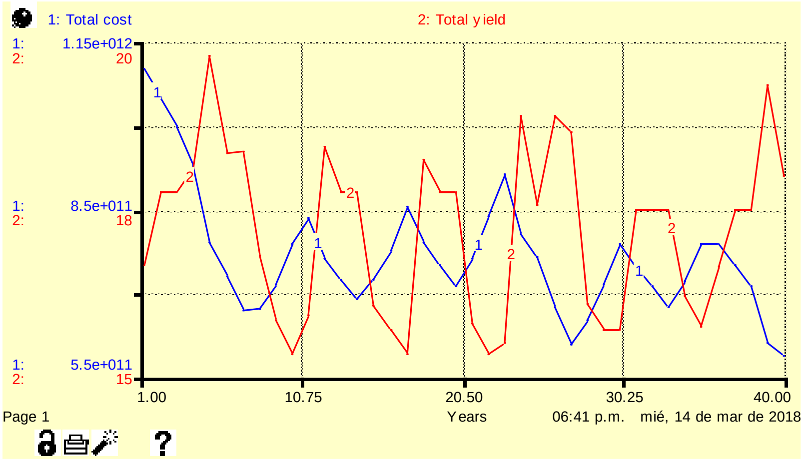
Verification of the model

Through the verification process, it is determined whether the operational logic of the model corresponds to the design logic; for this purpose, the behavior of cost, crop yield, price perceived by the producer, cultivated hectares and supply were verified..

Cost and yield of the crop

The crop yield, i.e. the number of tons of product obtained per hectare sown, is closely related to the cost per ton harvested, being an inverse relationship, where the variable cost acts dependent on the crop yield..

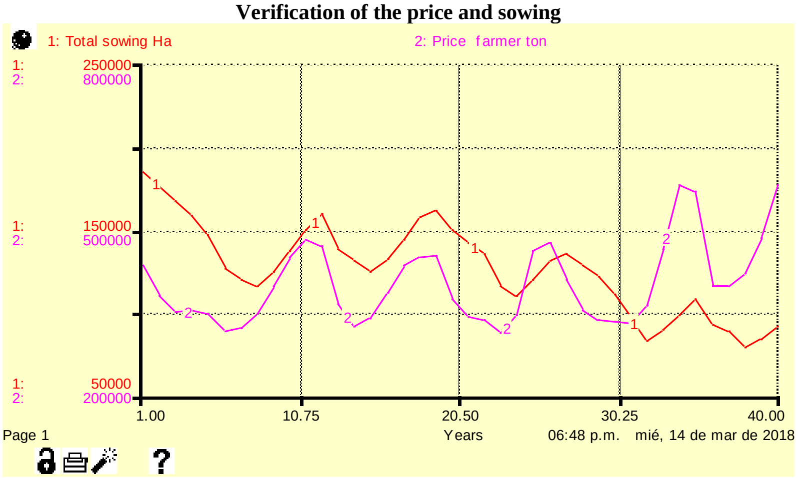
Verification of the cost and yield of the crop



Price received by the producer and sowing

The producer must make decisions in each sowing, which are influenced, among other aspects, by the price received per ton produced in the previous harvest, therefore, if the producer receives a low price in the following period will affect the trend of fewer hectares sown.

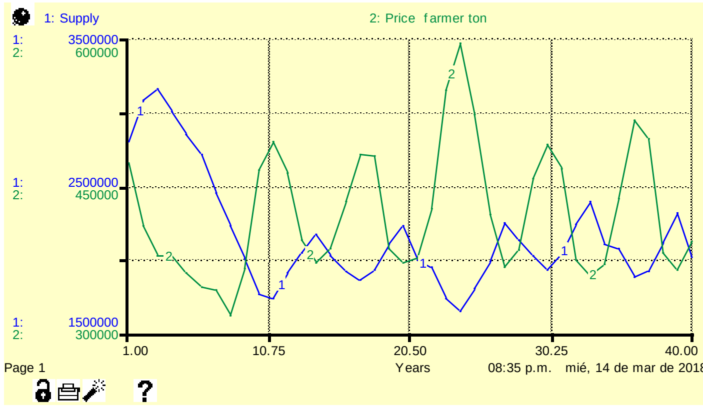
Verification of the price and sowing



Supply and price

The product supply has an effect on the price perceived by the producer, due to the fact that the product accumulation, added to the intermediation level, generates an imbalance before the demand, reflected on the growth or decrease of the price per ton.

Verification of the supply and price



Model validation

In order to validate the model's behavior, an analysis was performed on the variables dependent on the model and that define the system's behavior, such as hectares harvested, tons produced, per capita consumption of potatoes, price and cost, using the mean quadratic error between the historical data of a time series between 17 and 24 years, according to the availability of information and considering the following elements: (i) the number of hectares harvested, tons produced, per capita consumption of potatoes, price and cost, using the mean quadratic error between the historical data of a time series between 17 and 24 years, according to the availability of information and considering the following elements:

Aspects to evaluate in the validation of the model

Forecast error

$E_t = D_t - P_t$

MAD: *Mean Absolute Error*

MSE: *Mean square error* $$MSE_t = \frac{1}{N}\sum_{t=1}^{N} E^2$$

Standard deviation error $$\sigma = \sqrt{MSE}$$

MAPE: *Mean Absolute Percent Error*

Source; This investigation based on Bowerman, B. Pronósticos, Series de tiempo y regresión

Validation of sown hectares

According to the historical information reported by FAO [17] through its statistics portal, the hectares harvested in Colombia from 1991 to 2014 and the data obtained through the simulation of the system were compared.

The data obtained were:

Validation of harvested hectares

Description	*Absolute error*	*Quadratic error*
Sum	437846	12605185214
MAD	19902	
MSE		572962964
Error standard deviation		23937
MAPE	14,61%	

These data indicate that the average error in percentage of projected planted hectares is 14.61%, representing a low deviation between the behavior of the real system and the simulated one.

Validation of tons produced

According to the historical information reported by FAO [17] through its statistics portal, the information on the tons produced in Colombia from 1991 to 2014 was taken and contrasted with the data obtained through the simulation of the system.

The data obtained were::

Validation of tons produced

Description	*Absolute error*	*Quadratic error*
Sum	6036548	2841580041078
MAD	274389	
MSE		129162729140
Error standard deviation		359392
MAPE	13,52%	

These data indicate that the average error as a percentage of the tons produced is 13.52%, considering a low deviation between the behavior of the real system and the simulated one..

Validation of per capita consumption

According to the historical information reported by FAO [17] and the population data reported by DANE, the information was taken from the tons of potato produced in Colombia and consumed in average per capita from 1991 to 2014, contrasting it with the data obtained through the simulation of the system.

The data obtained were:

Validation of per capita consumption

Description	*Absolute error*	*Quadratic error*
Sum	145	1633
MAD	7	
MSE		74
Error standard deviation		9
MAPE	13,52%	

These data indicate that the average error in percentage of per capita consumption is 13.52%, considering a low deviation between the behavior of the real system and the simulated one.

Price and cost validation

According to historical information reported by the Corporación de Abastos de Bogotá (Corabastos), which represents the point of greatest food transaction in the country, information was taken on historical prices and costs of the product from 2000 to 2013, contrasting it with the data obtained through the simulation of the system..

The data obtained were:

Tabla Nº1. Price validation

Description	*Absolute error*	*Quadratic error*
Sum	1.451.336	183.815.074.017
MAD	96.756	
MSE		12.254.338.268
Error standard deviation		110.699
MAPE	20,14%	

These data indicate that the average error in percentage of the price received by the producer is 20.14%, and although the deviation is greater compared to previous variables, it is considered a good representation of the behaviour of the system.

Cost validation

Description	*Absolute error*	*Quadratic error*
Sum	1.219.443	133.582.219.433
MAD	81.296	
MSE		8.905.481.296
Error standard deviation		94.369
MAPE	20,33%	

These data indicate that the average error in percentage of the producer's cost is 20.33%, and although the deviation is greater compared to the previous variables, it is considered a good representation of the real behavior

APPENDIX D : (TESTING OF ASSUMPTIONS FOR MULTIVARIATE GENERALIZED LINEAR MODEL)

For the execution of the multivariate generalized linear model, the assumptions of homoscedasticity and normality of the variables were previously validated, so as to guarantee the validity of the model, as shown below

HOMOSCEDASTICITY AND NORMALITY TEST OF THE MODEL OF POST-CONFLICT AND CLIMATE CHANGE: PRODUCTION, PRODUCT COST AND FINANCIAL PERFORMANCE

Homoscedasticity test

$H_0 = \sigma_1^2 = \sigma_2^2$	There is no variation in the residuals of the variable tons produced, cost of the product and profit in the different models (post-conflict with and without climate change modifications).
$H_1 = \sigma_i^2 \neq \sigma_2^2$	There is variation in the residuals of the variable tons produced, cost of the product and profit in the different models (post-conflict with and without climate change modifications)

Contraste de Levene sobre la igualdad de las varianzas error[a]

	F	gl1	gl2	Sig.
TonProduced	,780	1	78	,380
Cost	,520	1	78	,473
Profit	,296	1	78	,588

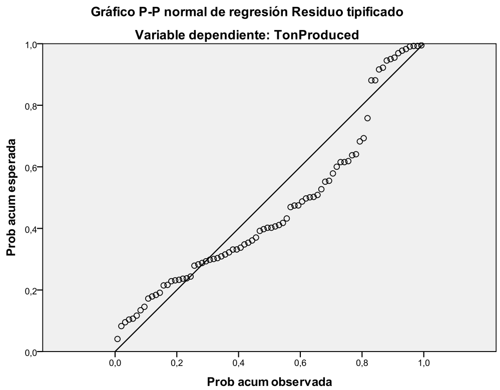
Contrasta la hipótesis nula de que la varianza error de la variable dependiente es igual a lo largo de todos los grupos.

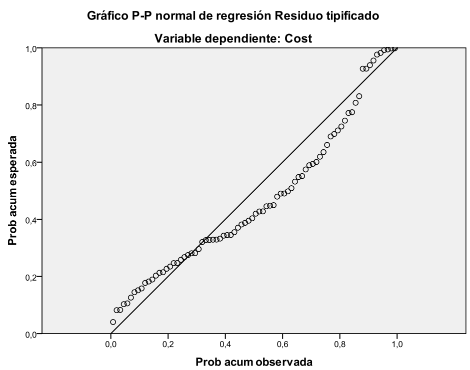
a. Diseño: Intersección + Scenario

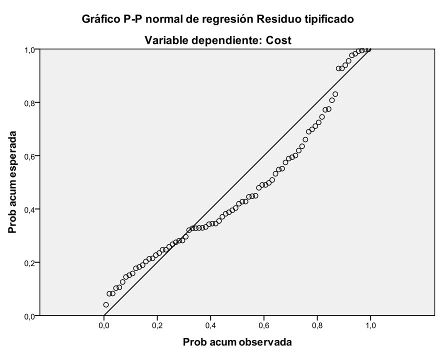
$F_{0,05;1;78}$ =3.96>0,78; $F_{0,05;1;78}$ =3.96>0,52; $F_{0,05;1;78}$ =3.96>0.296

- **Decision:** T o accept the null hypothesis.
- **Conclusion:** At a significance level of 0.05, the null hypothesis that there is homogeneity in the variances of the residuals of the variable tons produced, cost of the product and profit, cannot be rejected.

Normality test







Through the P-P graphs it is observed that the residuals of tons produced, cost and profit are close to a straight line, which allows us to accept the assumption of normality.

HOMOSCEDASTICITY AND NORMALITY TEST OF THE MODEL WITH COLLABORATIVE POLICY IN DISTRIBUTION CENTERS: PRODUCTION, PRODUCT COST AND FINANCIAL PERFORMANCE

Homoscedasticity test	
$H_0 = \sigma_1^2 = \sigma_2^2$	There is no variation in the residuals of the variable tons produced, cost of the product and profit in the different models (collaborative public policy and non public policy)
$H_1 = \sigma_i^2 \neq \sigma_2^2$	There is variation in the residuals of the variables tons produced, cost of the product and profit in the different models (collaborative public policy and non public policy)

Contraste de Levene sobre la igualdad de las varianzas error[a]

	F	gl1	gl2	Sig.
TonProduced	,138	1	78	,712
Profit	2,969	1	78	,089
Cost	,025	1	78	,875

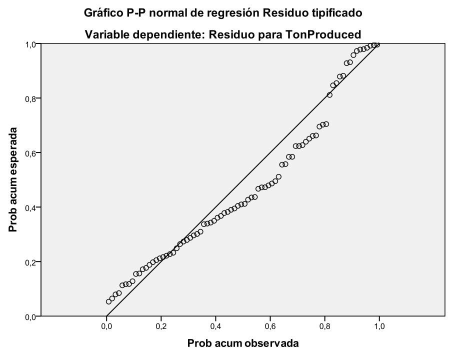
Contrasta la hipótesis nula de que la varianza error de la variable dependiente es igual a lo largo de todos los grupos.

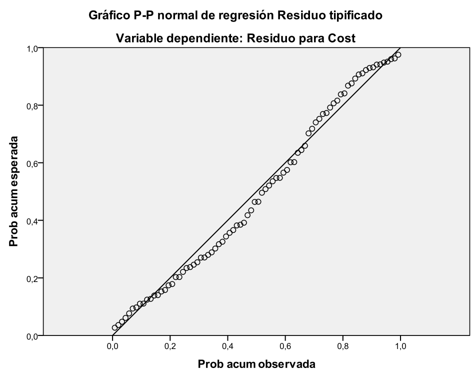
a. Diseño: Intersección + Scenario

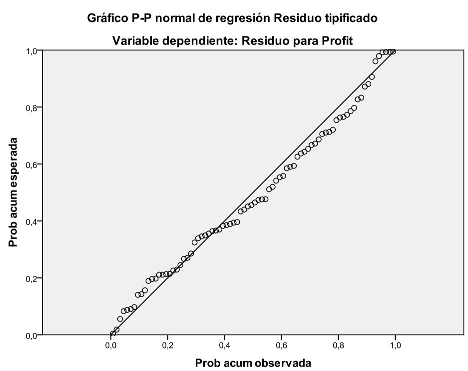
$F_{0,05;1;78}$ **=3.96>0.138;** $F_{0,05;1;78}$ **=3.96>2.96;** $F_{0,05;1;78}$ **=3.96>0.25**

- **Decision:** To accept the null hypothesis.
- **Conclusion:** At a significance level of 0.05, the null hypothesis that there is homogeneity in the variances of the residuals of the variable tons produced, cost of the product and profit, cannot be rejected..

Normality test







Through the P-P graphs it is observed that the residuals of tons produced, cost and profit are close to a straight line, which allows us to accept the assumption of normality.

APPENDIX E (MULTIVARIATE GENERALIZED LINEAR MODEL: POST-CONFLICT AND CLIMATE CHANGE ON PRODUCTION, PRODUCT COST AND FINANCIAL PERFORMANCE)

To contrast the hypotheses proposed in the chapter 1, subsection 4.2, the statistical software SPSS was used, analysing the results of crop yield, cost per tonne produced and gross financial margin with the model applied for the evaluation of the effect of climate change and post conflict armed in the agricultural sector, particularly the potato. This analysis was carried out using a general multivariate linear model: The null hypothesis and the alternate hypothesis are shown below:

Inter-subject effects test

Factores inter-sujetos

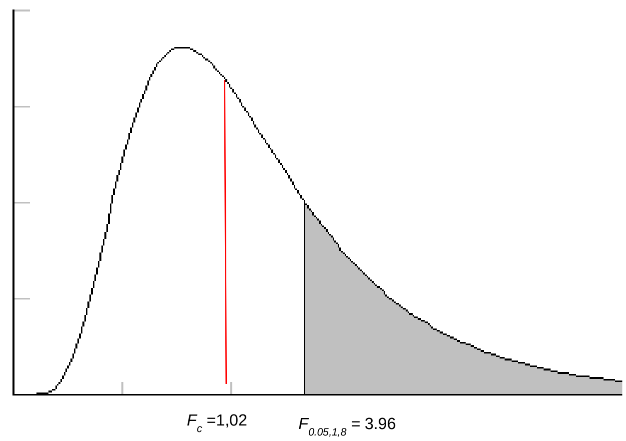
		Etiqueta del valor	N
Scenario	1	PostConfClimateChange	40
	2	PostConfClimateNoChange	40

Pruebas de los efectos inter-sujetos

Origen	Variable dependiente	Suma de cuadrados tipo III	gl	Media cuadrática	F	Sig.
Modelo corregido	TonProduced	1,281E11	1	1,281E11	1,020	,316
	Cost	4,301E21	1	4,301E21	,293	,590
	Profit	,015[c]	1	,015	2,530	,121
Intersección	TonProduced	3,792E14	1	3,792E14	3019,229	,000
	Cost	4,491E25	1	4,491E25	3063,792	,000
	Profit	2,016	1	2,016	328,476	,000
Scenario	TonProduced	1,281E11	1	1,281E11	1,020	,316
	Cost	4,301E21	1	4,301E21	,293	,590
	Profit	,015	1	,015	2,530	,121
Error	TonProduced	9,797E12	78	1,256E11		
	Cost	1,143E24	78	1,466E22		
	Profit	,479	78	,006		
Total	TonProduced	3,892E14	80			
	Cost	4,605E25	80			
	Profit	2,510	80			
Total corregida	TonProduced	9,925E12	79			
	Cost	1,148E24	79			
	Profit	,494	79			

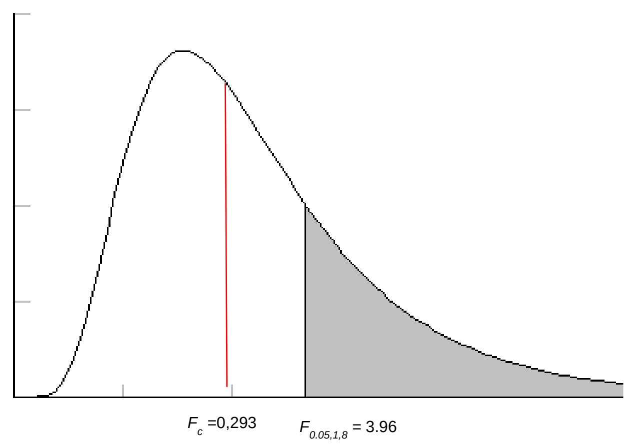
a. R cuadrado = ,013 (R cuadrado corregida = ,000)
b. R cuadrado = ,004 (R cuadrado corregida = -,009)
c. R cuadrado = ,031 (R cuadrado corregida = ,018)

Joint effect of post-conflict and climate change on production

<table>
<tr><td>• H₀ = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does not allow a significant improvement in the performance of the tons produced.</td><td rowspan="5">
</td></tr>
<tr><td>• H₁ = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does allow a significant improvement in the performance of the tons produced.</td></tr>
<tr><td>• With a significance level $\alpha = 0.05$ F ~ $F_{0,05;1;78} = 3,96 > F_c = 1.02$</td></tr>
<tr><td>• Decisión: To accept the null hypothesis.</td></tr>
<tr><td>• Conclusiones: The expected positive effect of the post-conflict in the agricultural sector of the potato is counteracted by climate change, without a significant improvement over the yields produced.</td></tr>
</table>

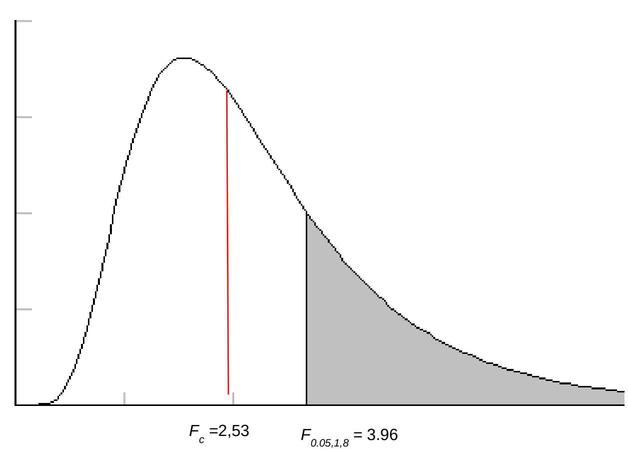
Joint effect of post-conflict and climate change on the cost of the product

- H_0 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does not allow a significant improvement in the cost performance of the product.
- H_1 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does allow a significant improvement in the cost performance of the product.
- With a significance level α = 0.05 F ~ $F_{0,05;1;78}$= 3,96 >F_c = 0.293
- **Decision:** To accept the null hypothesis.
- **Conclusions:** The expected positive effect of the post-conflict in the agricultural sector of the potato is counteracted by climate change, without a significant improvement over the cost of the product.



Joint effect of post-conflict and climate change on financial performance

- H_0 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does not allow a significant improvement in the performance of the financial rewards perceived by the producer.
- H_1 = Despite a more favourable environment in the agricultural sector after the armed conflict, climate change conditions, particularly in the potato sector, does allow a significant improvement in the performance of the financial rewards perceived by the producer.
- With a significance level α = 0.05 F ~ $F_{0,05;1;78}$= 3,96 >F_c = 2.53
- **Decision:** To accept the null hypothesis.



• **Conclusions:** The expected positive effect of the post-conflict in the agricultural sector of the potato is counteracted by climate change, without a significant improvement in the performance of the financial rewards perceived by the producer.	

APPENDIX F (MULTIVARIATE GENERALIZED LINEAR MODEL: COLLABORATIVE PUBLIC POLICY ON PRODUCTION, PRODUCT COST AND FINANCIAL PERFORMANCE)

To contrast the hypothesis presented in the chapter 2, numeral 4.2, the statistical software SPSS was used, analyzing the results of crop yield, cost per ton produced and gross financial margin with the model applied for the evaluation of public policy aimed at logistical collaboration in the agricultural sector, particularly the potato, through distribution centers. This analysis was carried out using a general multivariate linear model: The null hypothesis and the alternate hypothesis are shown below:

Inter-subject effects test

Factores inter-sujetos

		Etiqueta del valor	N
Model	1	Collaborative policy	40
	2	No policy	40

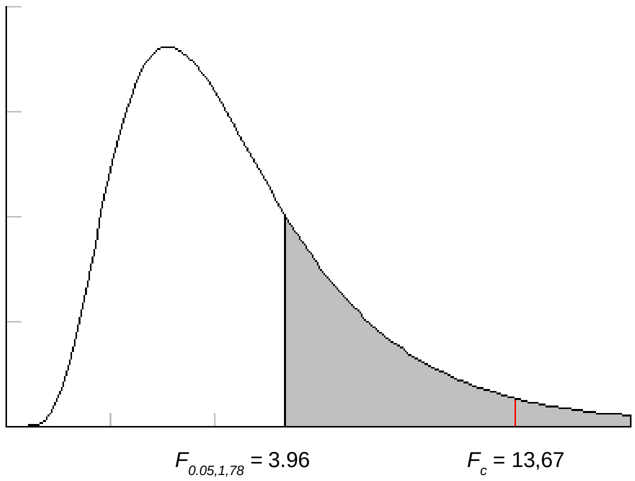
Pruebas de los efectos inter-sujetos

Origen	Variable dependiente	Suma de cuadrados tipo III	gl	Media cuadrática	F	Sig.
Modelo corregido	Ton produced	1,486E12	1	1,486E12	13,676	,000
	Profit	1,877E25	1	1,877E25	7,965	,006
	Cost	1,668E10	1	1,668E10	7,923	,006
Intersección	Ton produced	4,135E14	1	4,135E14	3804,979	,000
	Profit	4,900E26	1	4,900E26	207,969	,000
	Cost	9,023E12	1	9,023E12	4284,941	,000
Model	Ton produced	1,486E12	1	1,486E12	13,676	,000
	Profit	1,877E25	1	1,877E25	7,965	,006
	Cost	1,668E10	1	1,668E10	7,923	,006
Error	Ton produced	8,477E12	78	1,087E11		
	Profit	1,838E26	78	2,356E24		
	Cost	1,642E11	78	2,106E9		
Total	Ton produced	4,235E14	80			
	Profit	6,926E26	80			
	Cost	9,204E12	80			
Total corregida	Ton produced	9,963E12	79			
	Profit	2,026E26	79			
	Cost	1,809E11	79			

Source: This investigation

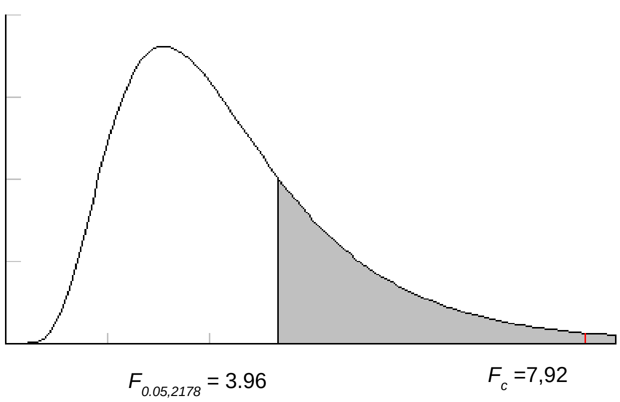
Hypothesis contrast: Collaborative public policy and effect on production

- H_0 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector does not influence production.
- H_1 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, influences production.
- With a significance level α de 0.05 $F \sim F_{0,05;1;78} = 3{,}96 < F_c = 13{,}67$
- **Decision:** Reject the null hypothesis.
- **Conclusions:** There is insufficient evidence to affirm that the implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, does not influence production.

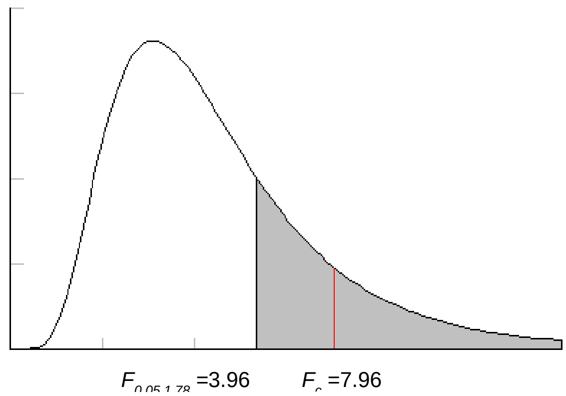


Hypothesis contrast: Collaborative public policy and effect on product cost

- H_0 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector does not influence the cost of the product.
- H_1 = Implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, influences the cost of the product.
- With a significance level α de 0.05 $F \sim F_{0,05;1;78}= 3{,}96 < F_c = 7{,}92$
- **Decision:** Reject the null hypothesis.
- **Conclusions:** There is insufficient evidence to affirm that the implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, does not influence the cost of the product.



Hypothesis contrast: Collaborative public policy and effect on profit

<table>
<tr><td>• H_0 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, does not influence the financial profitability perceived by the producer.</td><td rowspan="5">
</td></tr>
<tr><td>• H_1 = The implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, if it influences the financial profitability perceived by the producer.</td></tr>
<tr><td>• With a significance level α de 0.05 $F \sim F_{0,05;1;78} = 3{,}96 < F_c = 7{,}96$</td></tr>
<tr><td>• Decision: Reject the null hypothesis.</td></tr>
<tr><td>• Conclusions: There is insufficient evidence to affirm that the implementation of a public policy through collaborative distribution centers in the agricultural sector, particularly in the potato sector, does not influence the financial profitability perceived by the producer.</td></tr>
</table>

APPENDIX G (SENSITIVITY ANALISYS)

From the results obtained on the most favorable behavior in the system by effect of the collaborative policy through distribution centers, are evaluated the dependent variables of crop yield, cost, tons produced and perceived utility.

This sensitivity analysis consists of the variation of the parameters (policy levers) of duration of the public-private relationship (>15 years) and the level of encouragement (30%) for an adequate definition of the segmentation of the network of distribution centers.

The output variables obtained through the different runs of the model correspond to a set of 40 data. To do this, it was checked whether the variables follow a normal distribution.

The data obtained follow another type of distribution, different from the normal distribution, therefore, the confidence (CI) interval was calculated as:

$$CI = \left[\bar{x} - \frac{s}{\sqrt{r\alpha}}\right], \left[\bar{x} + \frac{s}{\sqrt{r\alpha}}\right]$$

Where:

r= number of replies

α= level of rejection

$\bar{x}=\frac{1}{r}\sum_{i=1}^{n} x_i$

$$s = \left(\frac{1}{r-1}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{1/2}$$