Investigation note

Optimal associativity in rural areas of Ecuador using game theory

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Abstract

Agriculture in Latin America and specifically in Ecuador seeks to solve self-consumption and sales needs. In Ecuador, thousands of households are currently engaged in agriculture, which represents 70 of the country's agricultural production and 60% of the food that makes up the basic basket. The objective of this research is to propose a model so that producers can work in agroecological associations using cooperative game theory, achieving to improve their productivity, coming to compete in a dynamism of costs, supply, demand, distance and time. A study with a mixed approach was conducted, since in the quantitative part, semi-structured surveys, descriptive analysis, as well as secondary information for the numerical mathematical model of cooperative game theory were used. In the qualitative part, being a little studied phenomenon, the sample size was 76 agro-producers, and the sampling was for convenience. For its part, the research design was non-experimental, cross-sectional since the data were collected in a single moment (2019). The survey consisted of 13 items, among which were their geographical location, socioeconomic characteristics of the producer and agricultural production, collection-commercialization and sale of the product, among others. The information from the survey was analyzed using descriptive statistics (frequencies, percentages and averages). Finally, using the results of the surveys and secondary databases, their location was georeferenced to simulate two comparative scenarios of working or not in association using the Matlab software. The findings suggest that it is important to work with a maximum of 20 producers per association, with the optimal number being less than 10 agro-producers, thus reducing productivity losses by 6.4% (14.4 kg) of production.

Keywords: agricultural planning, associativity, collectivity economy, commercialization.

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The agroecological approach

This approach acts as an ideological basin of attraction (Altier *et al*., 2012) that drains the concerns of an epistemic community in full growth and the militancy of producers mobilized around the solidarity economy towards a main channel constituted by an alternative paradigm of rural well-being. Agroecology is an alternative agriculture, which takes nature itself as a production model, avoiding dependence on chemical products to ensure the conservation and preservation of natural ecosystems and agroecosystems.

Agroecology fulfills this characteristic and even goes further, as it constitutes itself as a true philosophy of life (Heifer, 2016). Organic products are sold in specific markets and to a sectorized public and enjoy a premium price. This is because today, the demand for this type of products far exceeds the supply, in addition to the fact that, through marketing strategies, they are defined as exclusive products (Hair, 2004). Agroecological products; however, differ widely from organic ones because, despite having similar forms of production with respect to the environment and the non-use of agrochemicals, they pursue widely differentiated objectives.

These products aim to help regional economies and poor farmers subsist and prioritize self-consumption. In addition, many organic products are not of local or regional origin, but are produced with environmentally friendly techniques, but are exported to other countries or continents. In this sense, one of the requirements of agroecological products is that they must be marketed in the same region in which they were produced, both to collaborate with the regional economy and local food security and to maintain a reasonable price and be accessible to the entire society (Saal, 2015).

On the other hand, in the world there is a peasant sector with an estimated population of 65 million, which includes 40-55 million indigenous people who speak approximately 725 languages (Altieri and Toledo, 2011). Based on estimates from a decade ago, these peasant producers (average land size of 1.8 ha), produce 51% of the corn, 77% of the grains and 61% of the potatoes consumed in the region (Altieri, 2002). In Brazil alone, there are approximately 4.8 million family farmers (about 85% of the total number of agricultural producers) occupying 30% of the country's total agricultural land, controlling about 33% of the area sown with corn, 61% of beans and 64% sown with cassava, which produces 88% of the total cassava, and 67% of all grains.

In Ecuador, the peasant sector occupies more than 50% of the area destined to food crops such as corn, beans, barley and chili. In Mexico, peasants occupy at least 70% of the area cultivated with corn and 60% of the area of beans (Toledo *et al*., 2010). In the same way in Ecuador, the first agroecological experiences begin to develop since 1980, but it was years later that a control over organic production began to be established, incorporating participatory guarantee systems (PGS), which were born as an alternative to third-party certifications (TPC), legal regulations in favor of food sovereignty have also been developed, such as the Organic Law on the Food Sovereignty Regime (LORSA, for its acronym in Spanish) and the Constitution of the Republic (Intriago, 2018).

Currently in the city of Cuenca-Ecuador, agroecological associations are formed by people from the countryside who, in turn, saw an advantage in working together. Although most of their production is destined for self-consumption, a part is destined to the sale of the products. Unfortunately, reasons such as distrust in working together as an association, lack of information on the management of agroecological agriculture, lack of technical training, lack of competitiveness in the face of products imported from nearby countries, the low income they receive from their sales, as well as the high costs to be able to transport their products to the different markets, have triggered some problems in these associations.

Many prefer to work individually despite being associated, which has caused the waste of growth opportunities to improve their income, since agencies such as the Ministry of Agriculture and Livestock (MAG, 2014) have experts who give them training. Unfortunately, most do not attend these, therefore, they cannot know new techniques in agriculture and even other products that can be grown and offered to the market, thus achieving a decrease in production, and due to high costs, there is a demotivation in the distribution of products.

All these causes and consequences lead to the stagnation of enterprises. The central problem of the present research was the low competitiveness of non-industrialized agroecological production, which was carried out in canton Cuenca-Ecuador, so, as a main objective was to propose a mathematical model based on the cooperative game theory with the purpose of improving productivity in the distribution of agroecological products. A cooperative game is a pair (N, v) formed by a finite set $N=\{1, 2, \cdots, n\}$ and function $v: 2^N \rightarrow R$ that assigns to each subset S of N a real number $v(S)$ with the condition that $v(\emptyset)= 0$ (Peleg and Sudhölter, 2007).

Each element of the set N is a player and every subset of N is a coalition (Young, 2005). The function v is called the characteristic function of the game ($v(S)$ is considered a measure of the expectation of the coalition S) and in cases where there is no ambiguity, the game v is talked about, being understood as the set of players (Cabrera *et al*., 2019). According to game theory, a coalition is a group or association of subjects with a single purpose, which is to improve their utility, mathematically, it would be said that it is a set N of n individuals (Granot, 2010) that make up the 2^N coalitions (Jiménez-Losada, 2017).

A study with a mixed approach was conducted, since in the quantitative part, semi-structured surveys, descriptive analysis, as well as secondary information for the numerical mathematical model of cooperative game theory, were used. In the qualitative part, being a little studied phenomenon, the sample size was small, and the sampling was for convenience. For its part, the research design was non-experimental, cross-sectional, since the data were collected in a single moment (2019) (Hernández-Sampieri and Mendoza-Torres, 2018).

Study region

The Cuenca canton is the capital of the Azuay province, this being the third most important province in Ecuador and is made up of 22 rural and 15 urban parishes. According to the Territorial Ordering Plan of the municipality of Cuenca, 65.6% of the population is concentrated in the urban area of the canton and the remaining 34.4% is in the rural area (Sistema Nacional de Información, 2019). In Azuay, the production of new products has been generated thanks to the geographical location, which has been favorable; however, in the sales markets of Azuay, there is a low presence of agroecological products due to the little information that the population has about them.

Farmers have been able to improve their production with the support of MAGAP to produce agroecologically; however, the uncertainty of producers due to the lack of price control, for the sale of their products and for the acquisition of raw materials and inputs necessary for the production causes producers to prefer to engage in other activities (Rivera, 2019).

Sampling frame

To obtain the location points of the agro-producers of the study region, a Garmin 64 x GPS was used, later the change of geographical coordinates to UTM coordinates is carried out with the ArcGeek online software, obtaining values in (x, y). Once the georeferenced points have been defined, the characteristics of the producers are defined, with their respective restrictions particular to the case, to be able to survey them.

Sample size and sampling

To analyze the case study, we sought the area that has the highest agricultural productivity and where they do not work in association, of these, through the snowball technique, it was possible to contact the different producers one by one, reaching to obtain the information of 76 agro-producers, they were contacted in person in October, November and December, 2019 in the first hours of the morning, given that it was the moment they had time. The sampling was for convenience because the producers did not belong to an association; using the snowball technique, an agro-producer was contacted, who provided the information of another agro-producer and so on until completing the 76.

Primary information collection

Study subjects. There are two types, those that belong and those that do not belong to an association. The research was carried out with 76 non-associated agro-producers who belong to the rural parishes of the Cuenca canton, Ecuador.

Measuring instrument. A semi-structured survey of 13 items was applied, considering the following topics: belonging to an association, name and legal status of the association, land area destined for cultivation, places of sale of their products, type of product they grow, type of product they sell, cost of products, quantity of products, frequency of sale, availability of transportation, cost of sale, group for the sale, number of people who are grouped to sell, in addition to their geographical location, age, gender, level of education and the number of economic dependences.

The information from the survey was analyzed using descriptive statistics (frequencies, percentages, and averages). Finally, using the Matlab software, two comparative scenarios of working or not in association are simulated. The study period included the year 2019.

Secondary information

To model using cooperative game theory with transferable utility, the distances of producers, potential supply and demand were used.

Variable distance. One of the parameters necessary to formulate the game theory model is the distance; for this, the center of the parish was taken as a point (0. 0), its geographical coordinates: [-2.8951084, 79.0512559], UTM [x, y]: [716613.3, 9679814.7], each new UTM value of the agroecological producers surveyed is subtracted from the UTM value of the center and then, in order not to work with large values in the simulation, a division by 1 000 is made. Once the results of the simulation are obtained, we carry out the reverse process until obtaining values in geographical coordinates and we proceed to locate on the map.

Supply and demand variables. Based on the statistical data from the last Population and Housing Census of Ecuador carried out in 2010 by the National Institute of Statistics and Censuses (INEC, for its acronym in Spanish), Cuenca is made up of 22 rural and 15 urban parishes, for the purpose of this study, the 15 urban parishes of the canton were taken into account and according to the Territorial Ordering Plan of the municipality of Cuenca, 65.6% of the population is concentrated in the urban area of the canton and the remaining 34.3% is in the rural area (Gobierno Autónomo Descentralizado Municipal del Cantón Cuenca, 2019), in addition, the economically active population of the canton Cuenca is concentrated mainly in the urban area with 69% (Alcaldía de Cuenca, 2016); that is, the urban part is where most of the commercial area is located.

The potential market for agroecological fairs is all the people (209 245) who live in the city of Cuenca between the ages of 18 and 70 who consume agricultural products, being this segment of people who have the purchasing power for the consumption of these products (Instituto Nacional de Estadísticas y Censos, 2018).

Profile of agro-producers

The results of the surveys indicate that, in relation to age and gender, 76% of people who are engaged in the agricultural sector are women, compared to 24% who are men, with ages from 18 years, that they have been working in the field. Regarding the education level, 67% have only primary education. Sixty-seven percent belong to a legally constituted association, of them only 6.1% use land (13 331 ha), as a legal association. One percent of producers sell in the place of production (decentralized autonomous governments), the others prefer to go to wholesale markets for selling, which leads to analyze the distance and cost variables.

The most representative types of products that are grown are fruits, vegetables, meat and cheeses, of which legumes, vegetables and fruits are the most sold. Product prices have a reference to one unit of dollar, seeing it as a constant value for simulation. From the analysis of the supply, it is determined that the average sale is 2 271 kg, in the same way the sale time is every week, the products are mostly taken to sale through rent, whose cost is a function of the distance in a value of 5 USD, in this case they do not work in an organized manner and each one uses an individual means of transport.

The most significant variables in relation to supply and demand products were obtained from the survey, where vegetables and fruits predominate with 36.8%, followed by fruits with 25.8%, grains with 6.9%, medicinal herbs 4.9%, dairy products 4.9%, meat 3.6%, eggs 2.6%, smaller animals 1.7% and others 0.4%. In the same way, agro-producers work based on short value chains, which, according to Santacoloma (2016), is the proximity between consumers and producers. In this specific case, it was identified that producers sell their products in local fairs or wholesale markets in the canton.

Simulation input data using game theory

With the data on supply, demand, cost, places of sale and georeferencing obtained from the survey, the simulation was designed using game theory with transferable utility, additionally, the amortization variable (R= 0.6) was considered the cost of depreciation of land use, products (30 kg), transport in a period of 365 days, market and agroecological products, they are the average of the amount of products produced in rural sectors; the threshold distance (Dt= 3.8 km) is the maximum sales distance.

The location (0.0) is considered the center of the rural parish, based on this reference, the geographical location (distance) of each producer is obtained, as well as the supply (2 271 kg), demand and prices (4 $ kg), which allow calculating the constant of losses (0.5). The constant of losses refers to the average price difference between the agroecological producer and a wholesale market or shopping mall.

Simulation output data

When applying the mathematical model, it is obtained that the average of losses without associating is 15.4 (kg) of products, which represents 53.7%. This occurs because most producers offer the same products and begin to compete with each other, in this sense, it is necessary that they work and form an association, but that they do so in a technical way, considering the variables previously worked on.

From the simulations, we obtain that of the 76 producers, 8 main associations must be formed [producer x - producer y]: [1 - 15], [17 - 38], [18 - 3], [19 - 33], [20 - 24], [21 - 54], [22 - 10] and [23 - 11].

To the other producers, it is recommended that they must improve the supply and look for another demand in the different points of sale of the city of Cuenca. Once the first eight associations of two agro-producers are formed (Figure 1), the losses reduce to 14.4 kg, which means that with these associations, productivity is improved by 6.4%.

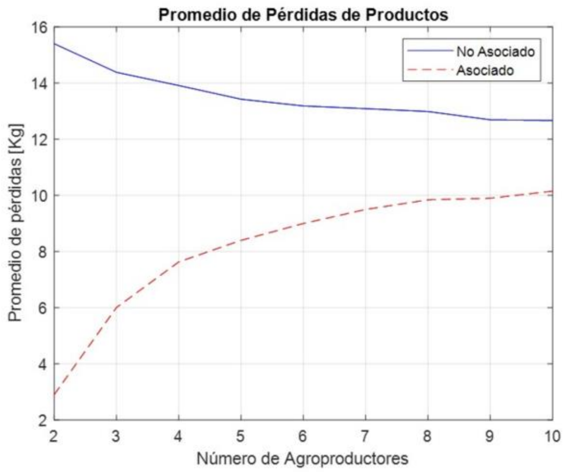

Figure 1. Comparison of losses of products when working or not associated in Cuenca-Ecuador.

In addition, it is observed that as the number of producers increases, the losses also increase, precisely because of the internal competition between producers. This would imply that not all producers can unite and generate a large association, with the current conditions, since their competition will be greater and therefore the losses (Figure 2).

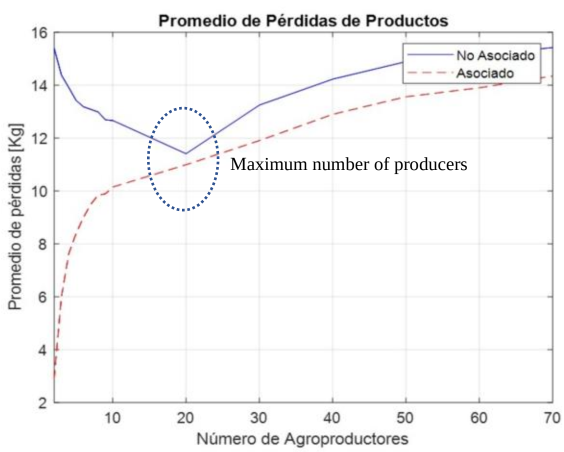

Figure 2. Average losses of the agro-producers studied in Cuenca-Ecuador.

Conclusions

Based on the results of the simulation, it was possible to verify that the 76 agro-producers are not technically well grouped, they currently prefer to work in isolation due to internal differences with the administration, too many procedures for its formation and they see meetings as a waste of time, which may be due to the fact that 67% have only primary education. The proposed model indicates that 8 associations must be formed, which will allow a 6.4% improvement in productivity.

These associations should be of a maximum number of 20 agro-producers, of which 10 are the optimal value because as the number of producers within an association increases, these losses increase, similar to what the law of diminishing returns affirms (Brown, 1984), that is, when the amount of variable input (number of producers) increases to a fixed unit (the association either in its facilities or infrastructure), returns begin to decrease.

To improve the productivity of producers, it is necessary to work in association, both to obtain economic resources and to be able to access training, but it is necessary to analyze the way in which they should be technically associated. It is necessary to better manage the products, land use, seeking not to have an internal competition between them. Although the production of its products is in a large percentage for self-consumption, it should be considered as future works complementary to the research, soft skills, having a sowing plan within the association, managing time and human resources.

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