The cost structure in a beef cattle industry in Rio Grande do Sul

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Abstract

Malted barley is the main raw material for brewing. In the last decade, Mexico has consolidated its position as the main beer brewer in the world. Freight and the operations related to the distribution of the harvest have an effect on the production costs and the amount of sawed, harvested and sold grain. This research study aimed at obtaining a mixed integer linear programming model and applying it in a malted-barley supply chain in Mexico. The model design a distribution network with minimal freight costs, considering variables like penalties/incentives, crop yields and costs of collecting points. This model allows identifying better scenarios that could be configured according to the agricultural contract that prevails in this chain. The results obtained in three possible scenarios showed through variations in the supply, demand and penalties / incentives the convenience of distributing 50% of the harvest obtained to each of the two malts with minimum costs between 329,210 and 598, 231 USD.

Keywords: Barley, supply chain, contract agriculture, logistic.

1. Introduction

Barley is one of the grains with the biggest growth at an international level (Ullrich, 2010). According to FAO (2015), in 2014, 146 million tonnes were produced in 49.8 million hectares, and were mainly used as forage, for human consumption and to produce malt for brewing. This cultivation is a fundamental supply for brewing industry highlighting the increase of exportations that this product has had because of malt. In 2012, the value of malt-beer exportations in Mexico was of 2,121 billions of dollars with an annual average growth of 7.53 %, which has allowed to place this country in the first place at an international level on top of beer producers like Holland, Belgium and Germany (Thomé and Soares, 2015).

Generally, the production in this agro-industrial sector takes place in complex networks integrated by multinational firms, as well as small and medium sized companies. This network is generally characterized for frequently being developed in one or two levels of distribution.

Regarding the redesign of distribution networks in several countries that produce malt beer, Köksalan *et al.* (2012) propose a mixed integer linear programming model (MILP) to evaluate the viability of opening new malt and brewing companies with the purpose of increasing the beer and malt production capacity in Turkey. This model aims at determining the location of new producers while fixed installation and freight costs decrease. In Canada, Wilson and Johnson (1995) analize, through a mathematical programming model, the effects on selling policies and prices in the barley sector in North America considering marketing strategies for US and Canada. Tolliver *et al.* (2011) discuss, based on a case study in North Dakota, a model of grains' distribution including barley, which aims at shortening the distance to the factories considering the own restriction of this distribution network like demand and the intalled capacities, besides evaluating with this model the use of Geographic Information Systems (GIS) and algorithms to identify the shortest route. In the North East of Europe, Lehtonen *et al.* (2010) present an example of modelling that aims at integrating multiple aspects typical of agriculture like the dynamic of the seed growth, the optimum levels of production and the hydrological conditions.

In Mexico, beer brewing has become more competitive each day, which has led to generate additional demand of malted barley looking for better quality that leads to a reduction of costs that appear along the supply chain. Particularly, this supply chain is integrated by framers, intermediaries, collecting points and malt producers who cultivate, harvest, distribute and process the grain, highlighting the administrative and operational control that malt producers have on it. Farmers take the role of workers within the indutrial process of malt in Mexico receiving the barley seed paid by regulating organisms of malt producers who establish the prices and the specifications to supply the harvested grain through the so called “agricultural contract”.

Agricultural contract is considered one of the main strategies for the industrialization of agriculture with the advantage that the contractor does not have to invest in soil and transfers the production costs and costs of risk to the producer. Among this risks are climate changes and plagues (Echanove and Steffen, 2005).

The cultivation of malted barley is mostly a rain-fed cultivation (spring-summer), when malt producers try to reduce their inventories with the purpose of having the necessary space to stock all the harvest.

According with the Information Service of Agro-food and Fishing Industries (SIAP) that depends on the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) in Mexico, during the 2015 spring-summer cycle 516,337 tonnes of grains were obtained in a surface of 283,008 cultivated hectares (SIAP, Information Service of Agro-food and Fishing Industries, 2017) representing an increase of 10 % with respect to 2013.

Within the agri-food supply chains, this chain has essential characteristics such as the high uncertainty in the supply caused mainly by the conditions of rain-fed cultivation obtaining historic variable profits that go from 0.7 to 4.5 tonnes per hectare, besides exiting a supply risk caused by damages produced by climate conditions. In 2015, the percentage of the damaged surface was 3 % which represents 8,392 hectares (SIAP, Information Service of Agro-food and Fishing Industries, 2017). In addition to the aforementioned, the collecting points and/or malt producers impose, according to the Mexican official regulation NMX-FF—043-SCFI-2003, penalties or incentives to farmers for the quality of the grain they receive. This penalties are mainly calculated based on the humidity contained in the grain and its physical condition at the moment of its reception. Finally, the geographic dispersion of farmers is another factor that complicates the logistics of distribution and delivery of goods mainly to zones far from the grain collecting points deteriorating the quality of the product and increasing the freight costs.

The Central Plateau that includes the states of Hidalgo, Puebla, México and Tlaxcala, is the main region that produces malted barley with nearly 70 % of the national production under rain-fed cultivation. Three of the four malted industries of the country are also located in this region (Aguilar and Schwentesius-Rindermann, 2004), being the state of Hidalgo the biggest producer of this type of grain, specifically in the plateau region of Hidalgo there are nearly 6,438 farmers dedicated to cultivate this grain.

According to the studies carried out by Ayala *et al.* (2010), Islas *et al.* (2003) it is estimated that 32 % of total production costs of malted barley under rain-fed conditions belong to the item of services being the most representative the freight costs associated with the delivery of grain form the harvest place to the collecting points and/or the malt producer. Aguilar and Schwentesius-Rindermann (2004) also notes that the freight costs can get to represent up to 10 % of the total production cost for a hectare of malted barley.

In addition to the aforementioned, the malt producers take over, through the agricultural contract, the operations to supply and distribute the grain, participating with their own collecting points and partner transportation to deliver and process the grain. This power of influence upon the chain also determines the planning and the way of configuring the distribution network design.

For this research study it is proposed a distribution network design of malted barley based on a MILP model considering the freight, stock, opening of collecting points and delivery penalties/incentives costs as factors of great influence upon prices, therefore upon the produced, consumed and sold amounts. The region of study was determined in the plateau zone of Hidalgo which is the region of the state with the highest production capacity of malted barley.

The rest of this paper is organized as follows: Literature review about logistic costs are presented en the Section 2. In Section 3 of this article, it is explained the method that was used in the study and it is described the mathematical formulation of MILP model proposed for the design of the distribution network of barley. Then, in Section 4, the obtained results and scenarios are shown based on this model, and finally, this article adds a discussion and the conclusions about the adequacy of this study.

2. Literature Review

Logistics is a key factor that contributes mainly to the financial positioning of a company, through the balance between performance and cost. Stepien *et al.* (2016) consider that a decisive factor to maintain a competitive advantage, which allows the company's leadership in the different consumer markets, is the systematic reduction of costs related to logistics operations. The relationship between logistics costs and business strategies play an important role in business planning, mainly influencing the implementation of new competitive strategies.

In the agri-food supply chain, logistics are activities associated within the process itself, to improve the quality of agricultural products. The logistical process find to improve and ensure the quality of agricultural products, reducing logistics cost (Zhang and Aramyan, 2009).

Logistics costs are usually include the costs associated with the processes of transportation and distribution, packaging, material handling, inventory maintenance, transportation management and storage, loading and unloading, management of information and communication (Stepien *et al.,* 2016). Of these processes, transport and distribution operations are those that cover the highest percentage of total cost and is the most important category of logistics cost (Orjuela-Castro *et al.,* 2016).

Logistics costs have a significant impact on a company's finances, and therefore affect economic profits along the supply chain (Hämäläinen *et al.* 2017; Waller and Fawcett, 2012; Kubon and Krasnodebski, 2010), representing approximately more than ten percent of total operating costs (Engblom *et al.*, 2012).

Particularly in the agri-food supply chain, the predominant costs in the structure of logistics costs are those related to the transport of products and their distribution (Wajszczuk, 2016). Transportation cost is composed of fuel cost, maintenance cost, depreciation cost, driver salaries and the value of losses during delivery (Ongkunaruk and Piyakarn, 2011). In addition, factors such as geographically dispersed collection in rural production areas, seasonality in the harvest and traceability requirements are others aspects that integrate transport costs in the agri-food supply chain.

Studies conducted by Wajszczuk (2016), Bosona and Gebresenbet (2013), Van der vorst *et al*. (2009) indicated that the costs associated with transportation are the ones with the greatest contribution in the structure of logistics costs and that they have a major impact on the competitiveness of the farmers who are part of an agri-food supply chain.

Other authors like Ongkunaruk and Piyakarn (2011) propose that farmer's main logistics cost is from material handling activities: harvest, postharvest, and grading.

In general, transportation and distribution is widely regarded as one of the most critical determinants of business success.

3. Materials and Methods

Based on the SIAP data (2017) the state of Hidalgo has 84 municipalities that produce malted barley, five of them have surfaces larger than 8,000 hectares for cultivation, which has allowed then to reach the first places of production at a local level.

This study considered the municipalities with the largest surfaces of production, surfaces from 8,000 to 12,000 and larger than 12,000 hectares available for cultivation. Afterwards, to analyze the design of the distribution network, 243 farmers were found in these places with surfaces larger than 20 hectares, representing altogether nearly 8,638 hectares available for cultivation.

Nine of the possible collecting points were also selected. They are distributed along the cultivation zone. These collecting points work as temporary warehouses which are traditionally under the supervision and regulations imposed by malt producers (Medellin, 1987), also the two malt producers where the harvested grain can be delivered are shown here (Figure 1).

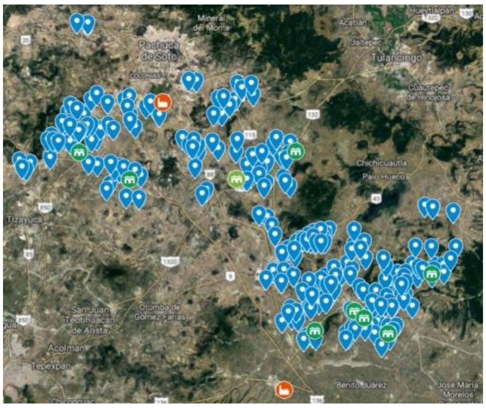

Figure 1: Geographic distribution of farmers, collecting points and malt producers

To calculate the distance between the location of the farmers, the collecting points and the malt producers it was used the Application Programming Interface (API) of Google Maps which allows, compared to the use of Euclidian distances and even some software based on Geographic Information Systems (GIS), to obtain a reliable estimate of the transfer distance (Fahui and Yanqing, 2011) proposing the optimum freight route considering the infrastructure of available roads, besides calculating the best travel time between a group of origins and a group of destinations. The process that was used to obtain distances based on API is shown in Figure 2.

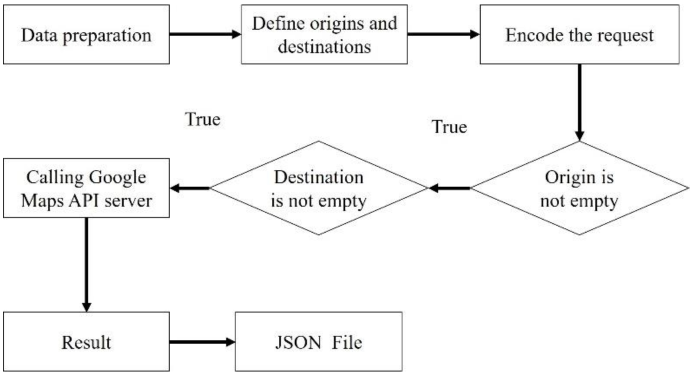

Figure 2: Process to obtain distances with the API of Google Maps

Regarding the levels of storage in the collecting points, they are considered warehouses classified as medium, big and very big, with capacities from 1,062 up to 9,402 tonnes depending on the type of infrastructure of each warehouse. In the case of malt producers, their capacity is, according to Caballero (2010), very superior to the capacity of the collecting points, however, according to the agreements entered by the malt producers, the farmers' harvest is distributed between the two, also considering certain limitations in the volume of harvest that can be sent directly from a farmer to the malt producer, choosing in this case to send the production through a collecting point.

In order to classify the farmers according to certain variables that might affect their harvest performance and that might lead to penalties or incentives, in this study, based on the proposals of Hardiman *et al*. (1990), a cluster analysis was carried out to identify those farmers with "similar" characteristics. This way, the variables in Table 1 were analyzed, where for example, if a farmer "i" was located in a region with very favorable climate, with a mostly fertile soil used for agriculture with a high potential of mechanization according to the suggested model this farmer would be included within a cluster "n" that would share homogeneous characteristics with "i". In this sense, three potential groups were identified through this multivariate technique (Figure 3). In the first one, 116 farmers were integrated for this case, characterized for being located in zones with a high potential for mechanization, good soil fertility and favorable climate for cultivation. In cluster 2, 96 malted barley farmers were identified who share characteristics like soils with certain portions not suitable for cultivation, located in favorable climates and with potential use for agriculture in some cases of manual type and with animal draught. Finally, 31 farmers were identified in cluster 3 which has favorable climates, soils with certain portions not suitable for cultivation and in most of them, mechanization is not possible so other ways must be used including manual agriculture with animal draught.

Table 1: Variables

Variable	Considerations
Type of climate	Sub-humid temperate climates with rain in summer and precipitations between 500 – 800 mm, are considered favorable for malted barley cultivation. On the other hand, regions with semi-arid temperate climate with precipitations between 400 – 600 mm may have a lower performance and some adverse conditions to cultivate, however, it is still a good scenario in terms of climate conditions for this product. In general, in the studied region, there are mainly these two climates.
Predominant soil	The groups of soil of phaeozem, luvisol and vertisol type are characterized for presenting a good fertility, in this sense, the regions that have a high percentage of soils with these characteristics are considered the most suitable ones for cultivation. The groups of leptosol and durisol soils are considered not suitable for cultivation, therefore their fertility is much lower compared to the aforementioned types.
Potential use for agriculture	This variable evaluates the mechanization characteristics, that is, the possibility of implementing the use of agro-industrial machinery and equipment with the purpose of accelerating productivity and efficiency. Among the types of agriculture that prevail in this region are the continuous agricultural mechanization, the seasonal manual agriculture with animal draught, and the regions not suitable for agriculture, the latter being the worst scenario for agricultural mechanization.

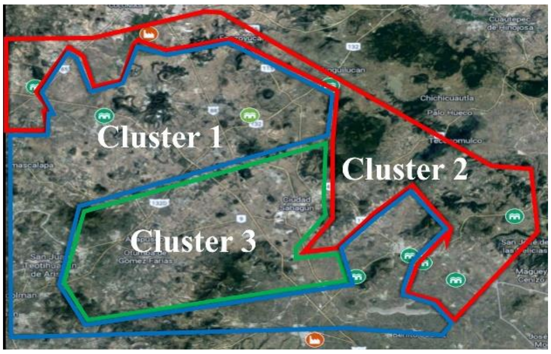

Figure 3: Clusters

3..1 Development of the model and formulation

The MILP model, formulated in this research, considers that malt producers, collecting points and farmers work collaboratively by means of an agricultural contract with the objective of designing a strategy that better suits the supplying needs of the grain of malt producers themselves who are the ones that take control over the supplying chain.

For the development of our proposal, the following cases are presumed:

- The risk of damage for this product is minimum.
- The production of malted barley obtained in the farmers' harvest is entirely used by malt producers, which are the only clients.
- The collecting points work as supervision points and also as temporary warehouses for malt producers. In the collecting points, quality tests of the grains are carried out; therefore, based on the NMX-FF—043-SCFI-2003 regulation, incentives or penalties are applied to harvest received from the farmers.
- The amount of product transported from a collecting point to a malt producer does not fall into any penalty or incentive in the delivery, as the quality of the grain has been previously controlled and it is maintained form the collecting point.
- Based on the agricultural contract, malt producers can limit the amount of grain they receive directly from the farmers (without going through a collecting point), besides defining the percentages that each producer will use of the total production.
- Freight is assumed with the enough capacity to move the grain.
- Freight costs are calculated according to Moreno and De la Torre (2011).

On the other hand, the following rates are used in the formulation of the model:

$i \in I$, which represents the group of farmers *i*.

$j \in J$, which represents the group of collecting points *j*.

$k \in K$, which represents the group of malt producers *k*.

The related decision variables for this case are:

x_{ij}, tonnes to transport from the farmer *i* to the collecting point *j*.

x_{ik}, tonnes to transport from the farmer *i* to the malt producer *k*.

x_{jk}, tonnes to transport form the collecting point *j* to the malt producer *k*.

Y_j, collecting point j is open or not

The parameters expressed in this model are:

c_{ij}, freight cost (in dollars) from the farmer *i* to the collecting point *j*.

c_{ik}, freight cost (in dollars) from the farmer *i* to the malt producer *k*.

c_{jk}, freight cost (in dollars) from the collecting point *j* to the malt producer *k*.

sum_i, available offer (tonnes of harvest) from the farmer *i*.

cap_j, storage capacity (demand in tonnes) of the collecting point *j*.

dem_k, demand (in tonnes) of the malt producer *k*.

$capm_k$, capacity to receive directly from the malt producer *k*.

P_{ik}, penalty / incentive applied to the farmer i in the malt producer *k*.

P_{ij}, penalty / incentive applied to the farmer i in the collecting point *j*.

f_j, opening cost (operation) of the collecting point *j*.

The mathematical model is expressed like*:*

Minimize

$$\sum_{i\in I}\sum_{j\in J} C_{ij}X_{ij} + \sum_{i\in I}\sum_{k\in K} C_{ik}X_{ik} + \sum_{j\in J}\sum_{k\in K} C_{jk}X_{jk} + \sum_{i\in I}\sum_{k\in K} P_{ik}X_{ik} + \sum_{i\in I}\sum_{j\in J} P_{ij}X_{ij} + \sum_{j\in J} f_jY_j \qquad (1)$$

With the restrictions:

$$\sum_{j\in J} X_{jk} + \sum_{i\in I} X_{ik} = dem_k \qquad \forall\, k \in K \qquad (2)$$

$$\sum_{i\in I} X_{ij} = \sum_{k\in K} X_{jk} \qquad \forall\, j \in J \qquad (3)$$

$$\sum_{j\in J} X_{ij} + \sum_{k\in K} X_{ik} \le sum_i \qquad \forall\, i \in I \qquad (4)$$

$$\sum_{i\in I} x_{ij} \le cap_j \qquad \forall\, j \in J \qquad (5)$$

$$\sum_{i \in I} x_{ik} \leq capm_k \qquad \forall\, k \in K \qquad (6)$$

$$\sum_{k \in K} x_{jk} = Y_j cap_j \qquad \forall\, j \in J \qquad (7)$$

$$x_{ij} \geq 0 \qquad \forall\, i \in I \,,\ \forall\, j \in J \qquad (8)$$

$$x_{ik} \geq 0 \qquad \forall\, i \in I \,,\ \forall\, k \in K \qquad (9)$$

$$x_{jk} \geq 0 \qquad \forall\, j \in J \,,\ \forall\, k \in K \qquad (10)$$

$$Y_j \in \{0,1\} \qquad \forall\, j \in J \qquad (11)$$

The objective function (1) is to minimize the opening fixed costs, the freight cost from the farmers to the collecting points, from the collecting points to the malt producers and from the farmers to the malt producers, as well as the penalties that a farmer might fall into. The demand of malt producers must be satisfied according to the restriction (2). The restriction (3) indicates that the amount of tonnes of malted barley sent from the farmer to the collecting point must be the same as the amount moved from the collecting point (transfer point) to the malt producer, that is, it represents a balance equation between the inputs and outputs in the collecting point preventing the accumulation of inventory at the end of the planning period. On the other hand, the restriction (4) points out that the amount of malted barley transferred from each farmer to the different collecting points or malt producers must not exceed the production capacity (available hectares for cultivation). Restriction (5) shows that the amount that is sent from the different farmers to the collecting points must not exceed their storage capacity; on the other hand, restriction (6) points out that the amount sent from the farmers to the malt producers must be smaller than the available capacity of reception, that is, malt producers only allow receiving directly (without going through a collecting point) certain tonnes of malted barley. Restriction (7) points out that a collecting point can only be open if all the storage capacity is used to send the malted barley to the malt producers. Finally, restrictions (8)-(11) define the non-negative and binary variables.

4. Results and Discussion

The proposed MILP model was solved with the MATLAB software, version R2015a. The results (Table 2) correspond to the baseline scenario that was generated considering the case in which each malt producer uses 50 % of the harvest; besides just allowing 5 % to be received directly from the farmer. Regarding the penalties/incentives, they are applied considering that cluster 1 is the most favorable one as it falls into incentives for the delivered product, while farmers of cluster 3, on the contrary, will receive penalties for not complying with the quality requirements. In this sense, and according to the conditions and characteristics of the cluster, the best performances will be for cluster 1 with a production of 4.5 tonnes of harvest per hectare.

This first scenario (Figure 4) indicates that the distribution network must consider the opening of six collecting points in order to satisfy the demand requirements that for this case are 46,958 tonnes of grain of malted barley.

However, given the high uncertainty about the demand and variations of performance levels that naturally presents this supplying chain, it turns out convenient to analyze other scenarios as of this model, considering (based on the agricultural contract) those options that enhance the network design. Therefore, the next section suggests and analyze other possible scenarios.

Table 2: Base Scenario

Havest distribution (%)		Received directly from the farmer (%)		Penalty / incentive (USD/t)			Performance (t/ha)			Total cost (USD)
Malt producer		Malt producer		Cluster			Cluster			
1	2	1	2	1	2	3	1	2	3	
50	50	5	5	-1.2	0	1.2	4.5	1.8	0.7	598,231

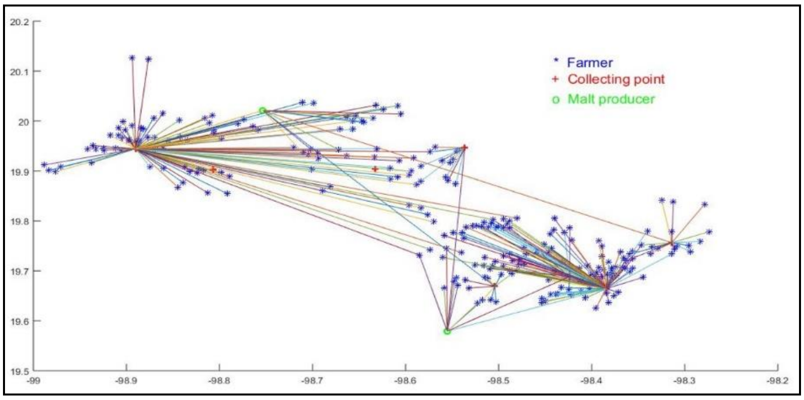

Figure 4: Base Solution

4.1. Scenarios

In the first scenario, there were considered variations in the percentages of production that malt producers use, these percentages fluctuate between 0 % to 100 % of use, considering that it is allowed to receive combinations between 5 % and 30 % of total production directly and that the highest performance in harvest and incentives are applied to cluster 1 farmers, while the lowest performances and penalties occur in cluster 3. The combinations of this scenario (Figure 5) showed that results get better for this network design with the balance of participation in the purchased production among malt producers. To increase the supply that the farmer receives directly, contributes to reduce total costs, being the best combinations for this scenario the ones showed in Table 3.

Table 3: Best combinations Scenario 1

Harvest distribution (%)		Received directly from the farmer (%)		Penalty / incentive (USD/t)			Performance (t/ha)			Total cost (USD)
Malt producer		Malt producer		Cluster			Cluster			
1	2	1	2	1	2	3	1	2	3	
50	50	10	10							579,598
50	50	20	20							543,702
50	50	20	10							543,702
40	60	10	20	-1.2	0	1.2	4.5	1.8	0.7	558,231
50	50	30	20							543.643
50	50	20	30							543,702
50	50	30	30							543,702

This scenario shows the advantage of distributing the harvest in a balanced way between the two malt producers, considering as best combinations the proportions of 50 % for malt producer 1 and 50 % of the harvest for malt producer 2. The results also indicate the convenience of maintaining the operation of even two collecting points in one scenario and in the other maximum six collecting points.

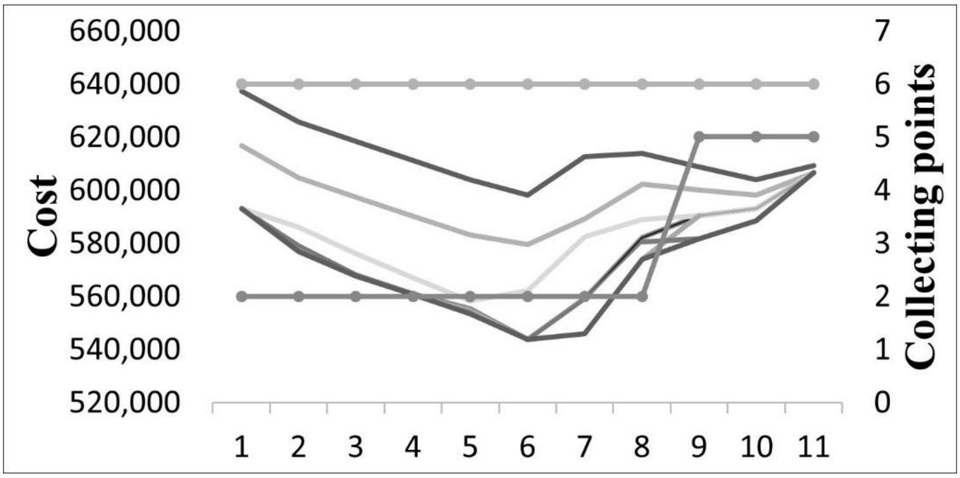

Figure 5: Combinations Scenario 1

In the event that the penalties/incentives would change in such a way that cluster 1 presents penalties, cluster 2 gets incentives in the delivery and cluster 3 remains unaffected, and, in addition, performances be of 1.8, 4.5 and 0.7 respectively for each cluster, based on the suggested model, the best obtained results are the ones showed in Table 4. It is observed that for this second scenario, favorable combinations still are those where production is distributed in a balanced way, also getting as result that two or even five collecting points must remain operating. Figure 6 shows the results for this second scenario.

Table 4: Best combinations scenario 2

Harvest distribution (%)		Received directly from the farmer (%)		Penalty / incentive (USD/t)			Performance (t/ha)			Total cost (USD)
Malt producer		Malt producer		Cluster			Cluster			
1	2	1	2	1	2	3	1	2	3	
50	50	5	5	1.2	-1.2	0	1.8	4.5	0.7	594,157
50	50	10	10							572,438
50	50	20	20							558,068
50	50	20	10							560,984
50	50	10	20							569,147
50	50	30	20							558,068
40	60	20	30							558,068
50	50	30	30							558,068

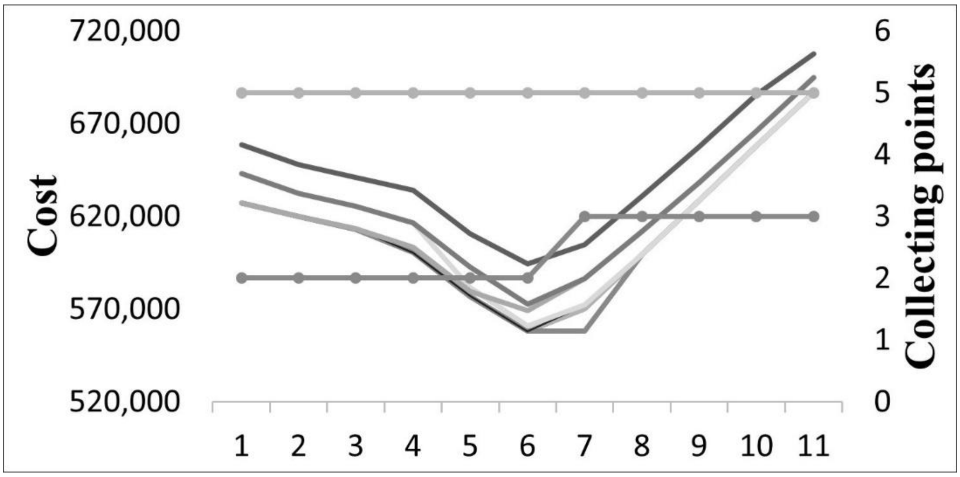

Figure 6: Combinations Scenario 2

Finally, while cluster 1 obtains low performances without penalties nor incentives in the harvest, cluster 2 obtains performances between 1.8 t/ha affected by penalties for the quality of the grain, and cluster 3 with high performances and with penalties, results like the ones showed in Table 5 are obtained. For these conditions, the scenario is considered like the most critical because the main farmers located in clusters 2 and 3 have the lowest performances which consequently generate very low levels of harvest.

In this scenario it is also observed that the distribution of production must be mainly for malt producer 1 with 90 % of the total and just the remaining 10 % should be acquired by malt producer 2; besides, based on this model, there is no viable solution where it is only permitted to receive just 5 % of the direct supply. As for the operation of collecting points for this scenario, they are considered between 2 or even 4 collecting points.

Table 5: Best combinations scenario 3

Harvest distribution (%)		Received directly from the farmer (%)		Penalty / incentive (USD/t)			Performance (t/ha)			Total cost (USD)
Malt producer		Malt producer		Cluster			Cluster			
1	2	1	2	1	2	3	1	2	3	
90	10	5	5	0	1.2	-1.2	0.7	1.8	4.5	INF
90	10	10	10							343,332
90	10	20	20							331,413
90	10	20	10							332,924
90	10	10	20							341,049
90	10	30	20							331,413
90	10	20	30							330,658
90	10	30	30							329.210

According to Figure 7 and Table 5, the best combinations for this scenario appear when malt producer 2 gets a smaller amount of production with respect to malt producer 1.

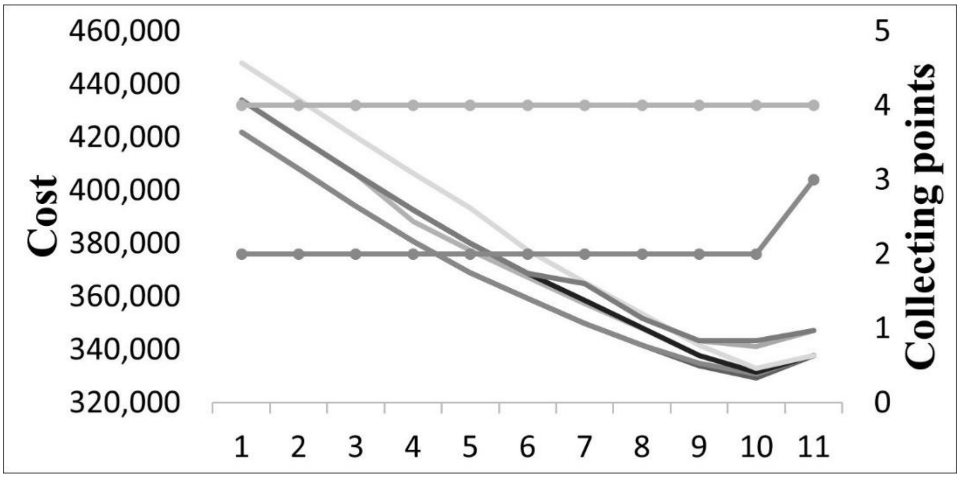

Figure 7: Combinations scenario 3

5. Conclusions

Analyzing the results and considering the model of agricultural contract that remains in this supply chain of malted barley, the best scenarios in which a supplying chain could be designed to distribute the grain from the farmer to the malt producer appear when there is a balance in the distribution of the grain that is purchased by the malt producers. Keeping this balance allows obtaining minimal costs in freight operations. One of the problems that supply chain (based on agricultural contract) face is the right allocation of harvest contributing to sustainable operations of the company that uses these supplies; therefore, this proposal helps reaching better decisions for this chain.

The fact that malt producers receive higher levels of grain directly from the farmer, also helps getting better results in the design of this distribution network, and also enhances the use of collecting points, opening only those that are necessary to operate the chain.

The proposed MILP model allows adequate crop allocation based on a distribution network design including key aspects such as uncertainty in demand, supply and penalties / incentives that are applied using clusters. However, it turns out convenient, for future research works, to include other variables that may have an influence in the performance of this chain such as the available infrastructure per producer, the financing needed for cultivation, the risks associated with plagues, among others.

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