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Article

Proposal for the grouping of small corn producers to achieve economic efficiency in the State of Mexico

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Abstract

In the State of Mexico, there is a great diversity of corn producers, from the most technified to those of subsistence, the latter are related to small production units, which often have problems for not reaching competitive prices in inputs and services derived from the low volume required per unit, increasing their costs above the average productive scale. The present work focuses on the economic efficiency of producers based on the comparison of average unit costs, for which a documentary analysis that optimizes these costs (mobilization of inputs, production, costs of services of agricultural work and machinery) is proposed. The grouping and association of producers that will allow such cost optimization is proposed. In the case of the mobilization of inputs and production, it was based on the load capacity of different transport units, while the acquisition of machinery was based on reducing the costs of tillage services and the size of the group of producers. The results indicate that the grouping for mobilization of improved seed (IPUIS) is 33-40 ha or 6-27 PUs reducing the cost by 55%, in the case of fertilizer (IPUF) is 15-25 ha or 3 to 14 PUs which allows to reduce the cost by 27%, the acquisition of machinery (IPUTR) is profitable from 40 ha and implies the integration of 6 to 27 PUs and a reduction of costs by 10%; while for the mobilization of production (IPUCM), it implies 4-10 ha or 1 and 3 PUs, which reduces costs by 38%. Finally, the comprehensive IPU suggests the grouping of 40 ha, which would reduce costs by 55, 38, 10 and 48%, respectively.

Keywords: economic efficiency, organization of small producers, production units.

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Introduction

In Mexico, corn (*Zea mays* L.) is the most important crop in the agricultural sector and represents a productive and consumption tradition (De los Santos-Ramos *et al*., 2017). In 2019, around seven million hectares were sown, and national production reached 27 million tons (SIAP, 2020). For the same year, 475 000 ha of corn were cultivated in the State of Mexico, which represents 54% of the agricultural area in the state (INEGI, 2020), with an average yield of 3.97 t ha^{-1} (lower than the national average of 4.07 t ha^{-1}) with a production of 1.87 million tons, which meant 44% of the value of production (SIAP, 2020).

There are several corn production systems in the state (Robles-Berlanga, 2016) from traditional of subsistence to the most technified (SIAP, 2013). Traditional systems are linked to small ejido or privately-owned production units (PUs) (Dufumier, 1993); according to the 2019 National Agricultural Survey, for white corn 64% of the strata were made up of sown area less than 5 ha and 36% with more than 5 ha in the State of Mexico (INEGI, 2020).

In the State of Mexico, 44% of the area sown in the state uses improved seed and 89% is fertilized (SIAP, 2018). Fifty-seven percent of the PUs use tractors and of these 85.8% are rented (INEGI, 2017). These data indicate that small producers must seek solutions to common problems, such as the lack of productive scale (Liendo and Martínez, 2001); however, this type of producers may be limited, among other things, by the lack of organizational culture, leadership, lack of public policies that promote organization (Barrios-Puente *et al*., 2020); nevertheless, unorganized producers lack benefits such as collection, access to credit and support for the purchase of machinery and inputs (Quintana, 2014). Belonging to an organization allows them not only collective purchases but economies of scale (Barrios-Puente *et al*., 2020).

The optimization of the use of the minimum resources invested by small producers is based on their organization to share expenses in the purchase and mobilization of inputs, production, as well as machinery that allows reducing unit costs and approaching the optimal level of production of the productive scale in which they are, for this reason the federal and state governments have promoted the union of producers to acquire credits and machinery; however, they rarely consider optimizing the use of the minimum resources required by the producer in relation to their level of production (SAGARPA, 2016).

The above situation raises the question: what is the area and how many producers should group on average to optimize the minimum resources required? It is difficult to establish the exact number of producers because there are a number of conditions; however, a reference can be established. This is fully aligned with the objectives 1 and 8 of sustainable development proposed by the UN, where the reduction of poverty and the increase of productivity are essential for the development of a country (CEPAL, 2016).

For this, a documentary analysis of resource requirements for the specific case of corn production is proposed as a viable solution so that producers can have a more competitive level of costs, as well as decide at what level of association they can or want to get involved. The analysis is performed for corn producers in the State of Mexico by Rural Development District (DDR, for its acronym in Spanish).

Materials and methods

Based on Varian (2010), profits are defined as the difference between total income (IT) and total costs (TC), total costs (TC) are defined as the monetary value of the quantities of factors that have been used in a given volume of production and sale of the commodity. Costs are divided into a) variable costs (TVC), which are the disbursements for the payment of all variable inputs incurred by the firm per unit of time to obtain production; and b) fixed costs (TFC), which are the expenses incurred by a firm per unit of time for all fixed inputs it uses and are paid regardless of whether there is production or not. That is: $\pi = \sum_{i=1}^{n} p_i y_i - \sum_{i=1}^{m} w_i x_i + b$ 1). Where yi= is the production of good i; pi= is the price of good i; xi= is the quantity used of the variable factor to produce good i; wi= is the price of the factor and b= is the fixed cost. The total mean cost (TMC), the mean variable cost (MVC) and the mean fixed cost (MFC) are obtained by dividing the TC, TVC and TFC by the volume of production obtained, the marginal cost (MgC) and the marginal income (MgI) in the change in the TC and total income due to the change of one unit in production (Figure 1a).

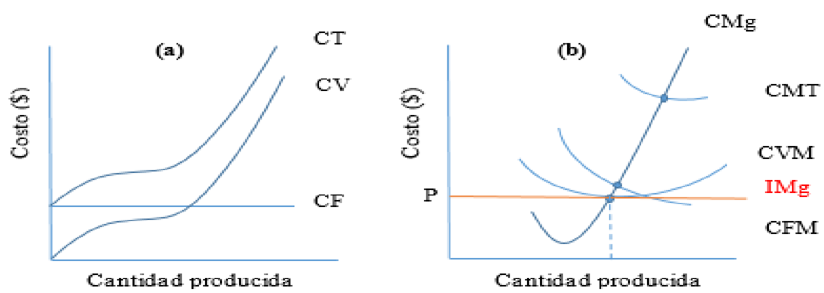

Figure 1. Curves of TC, VC, FC, TMC, MVC, MFC and MgC (García-Mata *et al*., 2003).

The principle of profit optimization in a competitive market indicates that the producer optimizes the use of their resources to the point where the MgI is equal to the MgC and equals the price (P), Figure 1(b); whereas the minimum MVC determines the minimum of the exploitation. The crossing of the minimum TMC and the MgC determines the exploitation optimum, from which the firm begins to make profits (Tomek and Robinson, 1991 cited by García-Mata *et al*., 2003).

Economic efficiency requires taking advantage of economies of scale (if they exist) to drive down costs (Case *et al*., 2012), a small producer often cannot take advantage of the economies of scale derived from the small volumes required, they have to take prices in the retail market, paying an extra price of the input or service or they underutilize the infrastructure by adapting to the standards closest to the productive scale (Figure 2a), when they should be in the unique optimal scale of the plant, which is where the total average cost is minimized (since there is no greater means to lower costs) and that is where economic efficiency is found (b).

Competition forces reaching point (b) in the long run (in the short term MgC equals LMC), although it takes an indeterminate time for them to adjust or exit the market, in the meantime they will be working with economic inefficiency (Figure 2). The methodological proposal then starts from the definition of 'economic efficiency', where the average unit costs are the basis for establishing a comparison between the costs of an average small producer and the unit costs of producers in economies of scale with respect to the mobilization of inputs, production and cost of service of agricultural work.

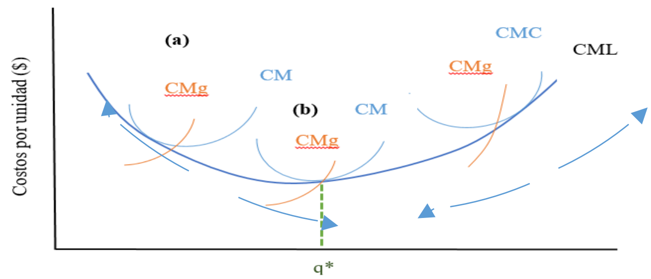

Figure 2. Unique optimal scale of the plant. Source: Case (2012).

The logic starts from knowing, in the first instance, the size of the average production units (PUs) in the State of Mexico, as well as their average unit costs of corn production in the state; on the other hand, propose the optimization of costs making use of economies of scale with respect to the mobilization of inputs, production and cost of service of agricultural work.

Based on this information, we estimated a number of hectares or ideal production unit (IPU) to carry out each of the activities of mobilization of seed, fertilizers, agricultural work and mobilization of the production; as well as a comprehensive IPU that considers the four activities. The unit cost in the state was established based on the total cost and volume mobilized per ha; unit transportation costs are based on an average of quotes for the rental of transport units in different districts and their load capacity (LC), which is the maximum weight of the load that a vehicle can transport safely and for which it was designed by the manufacturer (SCT, 2017).

To establish the minimum area required to reach the volumes of the different load units to transport inputs and grain mobilization; and the acquisition of machinery (tractor) based on their profitability, i Rural Development Districts (DDR, for its acronym in Spanish) and j transport units were considered. These areas are determined as: $ARIS_{ji}= LC_j / RS_i$ 1); $ARF_{ij}=LC_j/RF_i$ 2); $ARcTR_a=MI_a$ 3); $ARCM_{ji}=LC_j/YCT_i$ 4). Where: $ARIS_{ji}$ is the area required to optimize the cost of mobilizing improved seed or required area that has to be associated to occupy the LC of a transport unit j for the mobilization of seed from the producing house to the plot in the DDR i; LC_j is the LC of transport unit j; RS_i are the requirements of seed per hectare in the DDR i; ARF_{ij} is the area required to optimize mobilization costs of fertilizer or the area that has to be associated to occupy the LC of a transport unit j to mobilize fertilizer from the supply center to the plot.

In the DDR i; RF_i is the requirement of fertilizer in kg per ha in the DDR i. $ARcTR_a$ is the area required to acquire machinery; MI_a is the mechanization index, which indicates the number of ha from which a tractor is profitable (Ochoa-Bijarro, 2010); $ARCM_{ij}$ is the area required to optimize mobilization costs of corn, it is the minimum area that has to be associated to occupy the total LC of a transport unit j to mobilize the production of DDR i to the storage centers; YCT_i is the yield obtained in each DDR i. The determination of the IPU for seed (IPUIS), fertilizer (IPUF), machinery (IPUTR) and mobilization of the production (IPUCM) starts from the area required to carry out each of the activities by DDR and the size of the average PU in each DDR, to observe the different levels of integration, while the comprehensive IPU proposes the minimum area required and the association of PUs by DDR for the four activities and level of integration (equations 5 to 8). $IPUIS_i = ARIS_{ij}/PU_i$ 5); $IPUF_i = ARF_{ij}/PU_i$ 6); $IPUTR_{ia} = ARcTR_a / PU_i$ 7); $IPUCM_i = ARCM_{ij}/PU_i$ 8).

Data

The load units selected in the present work refer to 1, 5, 8, 16, 30 and 40 t (SCT, 2017). The costs per unit of load were obtained from quoting via telephone seven local microenterprises that mobilize merchandise within a radius of no more than 20 km from the municipalities of San Felipe del Progreso, Ixtlahuaca, Jiquipilco, Almoloya de Juárez and Toluca, these municipalities were considered based on the high production and small size of the PUs. The unit costs of mobilization of seed and fertilizer, as well as the costs of agricultural work in the state refer to the regime of moisture by gravity-fertilized-improved (GIF) and they were obtained from SADER (2019).

The requirements for improved seed per hectare, doses and volumes of fertilizer in the State of Mexico by DDR were taken from INIFAP (2017). The hourly cost of tractor was estimated from the Mexican Chamber of the Construction Industry (CMIC, 2019), the hourly cost of the implements was obtained from Velasco and González (2007).

Results and discussion

Table 1 shows the unit cost of transporting units of 50 kg, according to the size of the load unit, based on the reference of the average unit cost in the state ($50.00 pesos) (SADER, 2019), all unit costs of load are below the reference, which reflects reductions in unit costs.

Table 1. Unit costs of local transport, 2019. Figures in pesos.

Load capacity LCi (t)† and number of bags 50 kg		Transportation cost	Unit cost per transfer of unit (50 kg) transported (50 kg)	Unit cost per loading and unloading (50 kg)	Total cost per unit of 50 kg	Cost reduction with respect to SADER (2019) ††
1 t (LC1)	20	900.00	30.00	15.00	45.00	10%
5 t (LC2)	100	3 666.67	22.67	14.00	36.67	26.66%
8 t (LC3)	160	5 300.80	21.88	11.25	33.12	33.76%
16 t (LC4)	320	9 859.20	20.31	10.50	30.81	38.38%
30 t (LC5)	600	16 500.00	19.00	8.50	27.50	45%
40 t (LC6)	800	20 800.00	18.00	8.00	26.00	48%

Own preparation, based on local freight quotations 2019 and SCT (2017). †LC1 and LC2= cabin of 1 and 5 T; LC3= box truck (1 axle) 6.5∗2.5∗2.4 m for dry load; LC4= torton (2 axles) 6.5∗2.5∗2.4 m for dry load; LC5= semi-trailer tractor 15.9∗2.5∗2.5 dry load. LC6= trailer truck (5 axles) 31∗2.5∗2.5 dry load. Unit cost= (LCi/50kg)†† cost reduction: ((average unit cost SADER (2019)-unit cost LCi))/ average unit cost SAGARPA (2019).

The IPUIS, IPUF, IPUTR, IPUCM and comprehensive IPU are presented below, each one shows the area involved and the number of PUs that have to be associated to lower costs of mobilization of inputs, production and acquisition of machinery in a profitable way. The IPU for the mobilization of improved seed (IPUIS) was determined based on the data of the INIFAP technical agenda, which recommends between 25 and 30 kg ha^{-1} of seed in the state.

A minimum unit of load was considered to be a transport with a capacity of one tonne, which has a cost of 900 pesos (Table 1); that is, a unit cost per hectare of 22.5 pesos (40 units of 25 kg) as long as the total LC is used, which reduces the unit cost by 55% compared to the costs of SADER (2019) and involves between 33 and 40 ha or the association of 6 to 27 average PUs according to the DDR. Transport with LC of 5 t involving around 200 ha, a scenario that could benefit the DDR Tejupilco because it has average areas larger than the rest of the districts, which requires the organization of around 30 production units (Table 2).

Table 2. Estimates of the IPU for the mobilization of improved seed (IPUIS) by DDR.

DDR	Requirement of seed (t ha^{-1}) INIFAP (2017)	$PU_{average}$ (ha)	Requirement of area by load capacity (LCi)† ha^{-1}		PUIS††	
			LC1	LC2	1	2
Atlacomulco	0.025	1.98	40	200	20.2	101.01
Coatepec H.	0.03	2.35	33	166	14.18	70.92
Jilotepec	0.03	3.25	33	166	10.27	51.35
Tejupilco	0.025	6.59	40	200	6.07	30.35
Texcoco	0.025	2.04	40	200	19.61	98.04
Toluca	0.025	1.5	40	200	26.68	133.4
Valle de B	0.03	4.25	33	167	7.83	39.17
Zumpango	0.025	2.97	40	200	13.49	67.44

Preparation with freight data quoted in the State of Mexico, INEGI (2007) and INIFAP (2017). †LCi/requirement of input per ha by DDRi (eg., case LC1: 1 t/0.025 t). ††LCi/(requirement per $PU_{average}$ by DDRi; where LCi refers to LC1: 1 t, LC2: 5 t.

The IPU for fertilizer mobilization (IPUF) considers the volume required for fertilization of one hectare, which ranges between 326 and 556 kg (between 7 and 11 bags of 50 kg), while per average PU between 0.59 and 2.15 t is required, depending on the fertilizer needs and size of the PU by DDR. Estimates of SADER (2019) show that the average cost of mobilizing fertilizer per ha is 350 pesos (7 bags of 50 kg); that is, an average unit cost of 50 pesos per packaged unit of 50 kg. Table 3 shows the cost of carrying fertilizer per hectare from the distribution house to the plot.

In the case of fertilizer, the load unit of one tonne is sufficient for the average PU of Coatepec Harinas and Zumpango, which reaches a cost reduction close to 10%. However, for the PUs of Texcoco and Toluca, they present a significant underutilization (Table 3). IPUF (1). Therefore, it is advisable to partner to achieve higher volumes that allow reducing the cost. For the rest of the districts the LC is insufficient (Table 3). In the case of the load unit with a capacity of 5 t, the area involved ranges between 9 and 15 ha, the DDRs that require a greater number of producers were Toluca, Texcoco, Atlacomulco and the cost reduction represented 27%. For the transport unit of 8 t, a grouping between 14 and 25 ha or the integration between 3 and 14 PUs is required, for this LC the DDRs Atlacomulco, Coatepec Harinas, Texcoco and Zumpango are viable, with a cost reduction of 34%. For a unit of 16 t, Jilotepec, Tejupilco and Valle de Bravo require an integration of less than 10 PUs and it represents a reduction of 38%.

Table 3. Estimates of the IPU for fertilizer mobilization (IPUF) by DDR.

DDR	Requirement of fertilizer††† ($t\ ha^{-1}$)	$PU_{average}$ (ha)	Requirement of area by load capacity (LCi)† per hectare				IPUF††			
			LC1	LC2	LC3	LC4	1	2	3	4
Atlacomulco	0.407	1.98	2.46	12.29	19.66	39.31	1.24	6.19	9.9	19.81
Coatepec H.	0.391	2.35	2.16	12.79	20.46	40.92	0.92	5.44	8.71	17.41
Jilotepec	0.558	3.25	5.88	8.96	14.34	28.67	1.81	2.76	4.42	8.83
Tejupilco	0.408	6.59	17.7	12.27	19.63	39.26	2.69	1.86	2.98	5.96
Texcoco	0.326	2.47	1.99	15.34	24.54	49.08	0.8	6.21	9.94	19.89
Toluca	0.396	1.5	0.89	12.64	20.23	40.46	0.59	8.43	13.49	26.98
Valle de B.	0.391	4.25	7.08	12.78	20.44	40.89	1.66	3.00	4.80	9.61
Zumpango	0.326	2.97	2.87	15.34	24.54	49.08	0.97	5.17	8.28	16.55

Preparation with freight data quoted in the State of Mexico, INEGI (2007) and INIFAP (2017) † LCi/requirement of input per ha by DDRi (eg., LC1= Atlacomulco 1 t /0.407 t = 2.46). †† LCi/ (requirement of input per $PU_{average}$ by DDRi; where LC1: 1 t, LC2: 5 t, LC3: 8 t, LC4: 16 t. ††† Types of fertilizers refer to urea, calcium triple superphosphate, potassium chloride.

The IPU for the acquisition of machinery (IPUTR) allows reducing production costs, time and labor, since the state is characterized in the first place by the use of tractors with power greater than that required (70 Hp) in small areas (Ochoa-Bijarro, 2010), which implies higher fuel costs, secondly, the use of ha $tractor^{-1}$ below that recommended by FAO, resulting in long-term underutilization of equipment. In this sense, Hernández-Ávila (2020) mentions that 80 and 90 Hp tractors predominate in Zinacantepec with 13.8 ha $tractor^{-1}$, in Atlacomulco there is evidence of the use of tractors above 80 Hp in small PUs with 10.96 ha $tractor^{-1}$ (Larqué-Saavedra, 2012). Amecameca and Texcoco with similar situations, but with better use of 27.8 ha $tractor^{-1}$ (Sánchez-Hernández, 2014).

On the other hand, the mechanization index is a productive economic parameter and is determined from its profitability (a tractor is profitable if it meets the recommended hours of use for a correct amortization). In addition to the fact that its operations do not generate delays in the agricultural cycle (Ramírez-Valverde *et al*., 2007). This index is subject to the type of crop, tillage system and even the conditions of the soil and can also be affected by the relief.

Mechanization index one considers a tractor profitable from 25 ha tractor^{-1} (Masera-Cerutti, 1990), where the association of average PUs would range between 4 and 17. The second index is 40 ha tractor^{-1}, recommended for a conventional system of crops such as corn and beans. The third mechanization index is that recommended by FAO of 50 ha tractor^{-1} (Gutiérrez-Rodríguez *et al*., 2018) and the last involves 60 ha tractor^{-1} for minimum tillage for corn and beans (Ochoa-Bijarro, 2010). To determine the acquisition of machinery, the hourly cost of machinery to attend areas of 25, 40, 80 and 120 ha year^{-1} versus the cost of renting the service was estimated (Table 4).

Table 4. Estimate of hourly cost of tractor + implement vs machinery services.

Number of hectare attended	25	40	80	120
Hours of use year^{-1} (tractor 70 Hp)	75	120	240	360
Hourly cost ($)†	709.80	620.70	546.45	521.70
Hours of use year^{-1} (implement)	25	40	80	120
Hourly cost †† 20-disc harrow ($)	130.19	110.49	94.07	88.59
Hourly cost 3-disc plough ($)	89.90	74.18	61.08	56.72
Hourly cost seeder-fertilizer ($)	326.12	244.23	174.08	151.33
Machinery service†††	Cost tractor + implement			
20-disc harrow 800.00	839.99	731.18	640.51	610.29
3-disc plough 1 000.00	799.70	694.88	607.53	578.41
Fertilizer-seeder 750.00	1,035.91	864.93	720.53	673.03
Total 2 550.00	2,675.60	2,290.99	1,968.57	1,861.73

†= (CMIC, 2019) the hourly cost was calculated based on a cost of 760 000 with a useful life of 10 000. Working hours were estimated based on their use with implements. ††= Velasco and González (2007). For the disc harrow and the plough, a useful life of 3 000 h was considered, with a value in 2019 of 107 565 and 73 000 pesos, respectively, for the case of the seeder with a useful life of 2 000 h with a value of 127 080. †††= SADER (2019).

For the first index, it was preferable to pay for services than to acquire a tractor with its implements. However, from 40 ha, there is an hourly cost lower than that paid for the rental of machinery. Costs reduced by 10, 23 and 27%, respectively. For the purposes of this study, the index of Ochoa-Bijarro (2010) will be considered as the minimum area to acquire a tractor. The grouping of 40 ha was recommended for Toluca, derived from the small PUs, and implies the association of 27 PUs, for Atlacomulco, Texcoco and Coatepec H., the recommended area was 80 ha, that is, the association of 35 to 40 PUs, for Jilotepec, Tejupilco and Zumpango the grouping of 120 ha is suggested, which implies 30 and 40 PUs, which would allow for greater profitability (Table 5).

Table 5. Estimates of the IPU for machinery acquisition (IPUTR) by DDR.

DDR	$PU_{average}$	Average PUs associated to reduce costs in agricultural work for an area †		
		40 ha	80 ha	120 ha
Atlacomulco	1.98	20.2	40.4	60.61
Coatepec H.	2.35	17.02	34.04	51.06
Jilotepec	3.25	12.32	24.65	36.97

DDR	$PU_{average}$	Average PUs associated to reduce costs in agricultural work for an area †		
		40 ha	80 ha	120 ha
Tejupilco	6.59	6.07	12.14	18.21
Texcoco	2.04	19.56	39.12	58.68
Toluca	1.5	26.68	53.36	80.04
Valle de B.	4.25	9.4	18.8	28.2
Zumpango	2.97	13.49	26.98	40.47

Preparation with estimated data and INEGI (2007). †$Area_i$ /$PU_{average}$ by DDRi (eg., Atlacomulco 40/1.98= 20.2).

The organization of producers would allow it to be carried out at lower costs, according to the yields and the size of the average PU, the production volumes by PU vary between 6 and 15 t. Transport with capacity of 16, 30 and 40 t was considered, the requirement of association for a unit of 16 t is 1 and 3 PUs and it allows a reduction of 38%, a unit of 30 t requires the integration of 2 to 5 PUs and a reduction of 45%, finally, for the unit of 40 t, Valle de Bravo, Tejupilco and Jilotepec require the least grouping of PUs and it allows a reduction of 48% (Table 6).

Table 6. Estimates of the IPU for the mobilization of production (IPUCM) by DDR.

DDR	$PU_{average}$ (ha)	$Yield_{average}$ 2018 (t ha^{-1})	Area required (ha) for different load capacities (LC)†			IPUCM††		
			LC4	LC5	LC6	1	2	3
Atlacomulco	1.98	4.57	3.5	6.56	8.75	1.76	3.31	4.41
Coatepec H.	2.35	4.11	3.89	7.3	9.73	1.66	3.11	4.14
Jilotepec	3.25	3.15	5.08	9.52	12.7	1.56	2.93	3.91
Tejupilco	6.59	1.66	9.64	18.07	24.1	1.46	2.74	3.66
Texcoco	2.04	3.19	5.02	9.4	12.54	2.46	4.61	6.15
Toluca	1.5	3.77	4.24	7.96	10.61	2.83	5.31	7.08
Valle de B.	4.25	3.61	4.43	8.31	11.08	1.04	1.95	2.6
Zumpango	2.97	1.95	8.21	15.38	20.51	2.77	5.19	6.92

Preparation with available data from SIAP (2020); INEGI (2007). †= LCi /$yield_{average}$ by DDRi per hectare; ††= LCi/(yield per hectare DDRi∗$PU_{average}$ by DDRi); where LC4: 16 t, LC5: 30 t: LC6: 40 t.

The comprehensive IPU has the objective of grouping the smallest number of producers or production units to carry out the four activities jointly, in each one there is a reduction in costs from different load capacities, the number of producers and PUs was established based on the minimum area that is required to take advantage of the load unit with lower capacity (LC1), which refers to seed mobilization (derived from the low volume required per ha), which includes about 40 ha (Table 2), which was defined as the minimum area to carry out the four activities.

The mobilization of fertilizer for 40 ha requires a transport with a capacity of 16 t (Table 3). The mechanization index from which a tractor is profitable refers to 40 ha (Table 4), the mobilization of production from the foot of the plot to the storage and sales areas of 40 ha implies the carrying of 70 to 180 t according to the yield per hectare in each DDR, for which units with LC of 40 t are suggested. Two transport units are required in the case of Tejupilco and Zumpango, three for Jilotepec and Texcoco and four for the rest of the districts.

Conclusions

In the case of seed mobilization, the minimum area required includes between 33 to 40 ha, the ideal IPU would be the association between 6 (Tejupilco) and 27 PUs (Toluca), which reduces the carrying cost by 55%. In the case of Tejupilco, which has larger PUs, they allow groups with a greater number of producers, which translates into a greater reduction in costs. For the mobilization of fertilizer, the load unit of one tonne allows a reduction of 10% and implies the association of one to three producers, the unit of five tonnes reduces the cost by 27% and is recommended for the cases of Toluca, Texcoco and Atlacomulco due to the size of the association.

The grouping of producers for the acquisition of machinery (tractor) is 40 ha, which implies a reduction of 10% of the cost, it should be noted that this cost represents 20% of the total production costs. Regarding the mobilization of production, the union of few producers allows a reduction of important costs (1 to 3 PUs with a reduction in cost by 38%). The comprehensive IPU that considers seed and fertilizer, acquisition of machinery and mobilization of production suggests the grouping of around 40 ha to reduce costs by 55, 38, 10 and 48%, respectively. It should be noted that the integration and association of larger producers allows a greater reduction in costs, but implies a greater organization of producers, as well as logistics to carry it out successfully.

Cited literature

Barrios-Puente, J.; González-López, M.; Sangerman-Jarquín, D. M.; Pérez-Soto, F.; Jerónimo-Ascencio, F. y Rosales-Hortiales, A. 2020. La desorganización campesina de los maiceros de Huandacareo, Michoacán: razones y trascendencia. Rev. Mex. Cienc. Agríc. 11(7):1549-1563. https://cienciasagricolas.inifap.gob.mx/index.php/agricolas/article/view/2672/3541.

CMIC. 2019. Cámara Mexicana de la Industria de la Construcción. Catálogo de costos horarios de maquinaria 2019. México, DF. 212 p.

Case, K. E.; Fair, R. C. y Oster, S. M. 2012. Principios de microeconomía. 10ma. Ed. Prentice Hall. México, DF. 504 p.

CEPAL. 2016. Comisión Económica para América Latina y el Caribe. Agenda 2030 y los objetivos de desarrollo sostenible, una oportunidad para América Latina y el caribe. https://www.gob.mx/cms/uploads/attachment/file/311197/agenda-2030-y-los-objetivos-de-desarrollo-sostenible.pdf.

De los Santos-Ramos, M.; Romero-Rosales, T. y Bobadilla-Soto, E. E. 2017. Dinámica de la producción Agron. Mesoam. 28(2): 439-453. https://www.redalyc.org/jatsRepo/437/43750618008/html/index.html.

Dufumier, M. 1993. La importancia de la tipología de las unidades de producción agrícolas en el análisis diagnóstico de realidades agrarias *In*: sistemas de producción y desarrollo agrícola. Colegio de Postgraduados. 211-218 pp.

García-Mata, R.; García-Salazar, J. A. y García-Sánchez, R. 2003. Teorías del mercado de productos agrícolas. Colegio de Postgraduados. Montecillo, Texcoco, Estado de México. 382 p.

Gutiérrez-Rodríguez, F; Hernández-Ávila, J.; González-Huerta, A.; Pérez-López, D. J.; Serrato-Cuevas, R. y Laguna-Cerda, A. 2018. Diagnóstico de tractores e implementos agrícolas en el municipio de Atlacomulco, Estado de México. Rev. Mex. Cienc. Agríc. 9(8):1739-1750. https://doi.org/10.29312/remexca.v9i8.1549 .

Hernández-Ávila, J.; Gutiérrez-Rodríguez, F.; González-Huerta, A. y Bailón-Sáenz, H. C. 2020. Nivel de mecanización agrícola en el municipio de Zinacantepec, Estado de México. Ciencia Ergo-sum. 27(1)|e75:1-13. https://doi.org/10.30878/ces.v27n1a7.

INEGI. 2007. Instituto Nacional de Estadística y Geografía. Censo Nacional Agropecuario. Número y superficie total de unidades de producción en el Estado de México Instituto Nacional de Estadística y Geografía. https://www.inegi.org.mx/programas/cagf/2007/default.html#Tabulados.

INEGI. 2017. Instituto Nacional de Estadística y Geografía. Encuesta Nacional Agropecuaria 2017. Tabulado ena17_ent_maq02 y glosario. Instituto Nacional de Estadística y Geografía. México. https://www.inegi.org.mx/programas/ena/2017/default.html#Tabulados.

INIFAP. 2017. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Agenda Técnica Agrícola del Estado de México. Segunda edición. Impreso en México. 423 p. https://vun.inifap.gob.mx/VUN_MEDIA/BibliotecaWeb/_media/-agendas/4128_4825_Agenda_T%c3%a9cnica_Estado_de_M%c3%a9xico_2017.pdf.

INEGI. 2020. Instituto Nacional de Estadística y Geografía. Encuesta Nacional Agropecuaria 2019. Superficie cultivada y producción maíz amarillo y maíz blanco por entidad federativa. Datos de octubre de 2018 a septiembre de 2019. ena19_str_sup_cult_agri02.xlsx (live.com).

Masera-Cerutti, O. 1990. Crisis y mecanización de la agricultura campesina. Colegio de México, Ed. México, DF. 1990. 226 p.

Larqué-Saavedra, B. S.; Cortés-Espinoza, L.; Sánchez-Hernández, M. A.; Ayala-Garay, A. V. y Sangerman-Jarquín, D. M. 2012. Análisis de la mecanización agrícola de la región Atlacomulco, Estado de México. Rev. Mex. Cienc. Agríc. 4(esp.):825-837.

Liendo, M. G. y Martínez, A. M. 2001. Una alternativa para el desarrollo y crecimiento de las PYMES. Universidad Nacional de Rosario. Argentina. Escuela de Economía. Instituto de Investigaciones Científicas. Sexta jornada de ciencias económicas y estadística. Asociatividad. 311-319 pp.

Ochoa-Bijarro, J. G. 2010. Estudio del parque de maquinaria agrícola en el Estado de México. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP)-Centro Nacional de Estandarización de Maquinaria Agrícola (CENEMA). Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). 103 p. https://docplayer.es/36185232-Gobierno-del-estado-de-mexico-sedagro-estudio-del-parque-de-maquinaria-agricola-en-el-estado-de-mexico.html.

Quintana, A. L. 2014. Beneficios de la asociatividad en la pequeña agricultura. Conveagro. III Seminario Internacional de Servicios Financieros Rurales. Lima, Perú. 1-27 pp.

Ramírez-Valverde, B.; Ramírez-Valverde, G.; Juárez-Sánchez, J. P. y Cesín-Vargas, A. 2007. Tecnología e implementos agrícolas: estudio longitudinal en una región campesina de Puebla, México. Rev. Geo. Agríc. 38(1):55-70.

Robles-Berlanga, H. M. 2016. La pequeña agricultura campesina y familiar: construyendo una propuesta desde la sociedad. Entre diversidades. Rev. Cienc. Soc. Hum. 7(1):46-83. http://www.redgtd.org/centrodoc/bd_archivos/articulo_hector_robles.pdf.

SADER. 2019. Secretaría de Agricultura y Desarrollo Rural. Costos de producción primavera-verano 2018. Delegación del Estado de México. Área de producción estadística. Delegación de Edoméx de manera digital.

SAGARPA. 2016. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Programas SAGARPA. Reglas de operación 2016. Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. https://www.gob.mx/cms/uploads/attachment/file/44530/Reglas-Operacion-2016-sagarpa.pdf.

Sánchez-Hernández, M. A.; Ayala-Garay, A. V.; Cervantes-Osornio, R.; Garay-Hernández, M.; De la O-Olán, M.; Martínez-Trejo, G. y Velázquez-López, N. 2014. Diagnóstico de la maquinaria agrícola en Amecameca y Texcoco, Estado de México. Agric. Soc. Des. 11(4):499-516. http://www.scielo.org.mx/pdf/asd/v11n4/v11n4a4.pdf.

SCT. 2017. Secretaría de Comunicaciones y Transportes. Sobre el peso y dimensiones máximas con los que pueden circular los vehículos de autotransporte que transitan en las vías generales de comunicación de jurisdicción federal. Norma Oficial Mexicana NOM-012-SCT-2-2017. https://www.dof.gob.mx/nota_detalle.php?codigo=5508944&fecha=26/12/2017.

SIAP. 2020. Servicio de Información Agropecuaria y Pesquera. Superficie sembrada, producción, rendimientos, valor de la producción por entidad y municipio, año 2019. Secretaría de Agricultura y Desarrollo Rural. Ciudad de México. https://nube.siap.gob.mx/cierreagricola/.

SIAP. 2018. Servicio de Información Agroalimentaria y Pesquera. Estadística de uso tecnológico. Secretaría de Agricultura y Desarrollo Rural. http://infosiap.siap.gob.mx/opt/agricultura/tecnologia/Semilla%20Mejorada_Criolla.pdf.

SIAP. 2013. Servicio de Información Agroalimentaria y Pesquera. Situación actual y perspectivas del maíz en México 1996-2012. SADER. 123 p. http://www.campomexicano.gob.mx/portal_siap/Integracion/Estadisticaderivada/comercioexterior/estudios/perspectivas/maiz96-12.pdf.

Tomek, W. G. and Robinson, K. L. 1991. Agricultural product price. Third edition. Cornell University Press. Ithaca, New York. 367 p.

Varian, R. H. 2010. Microeconomía intermedia. Universidad de California, 8va. Ed. Bosch, A. Ed. Barcelona, España. 361 p.

Velasco, H. R. y González, U. J. 2007. Costo de operación o uso de maquinaria agrícola ¿Cómo evaluarlo? Instituto de Investigaciones Agropecuaria (INIA). Quilamapu. Transferencia Tecnológica y Extensión. Santiago de Chile. 42-51 pp.