The Economic Effects of Grazing in a Small-Scale Sheep Production System in Central Mexico via an Analysis of Scenarios

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Abstract

The objective was to assess grazing as an element of profitability and competitiveness of a small-scale sheep production system (SSSPS) in central Mexico and compare its economic performance by means of an analysis of scenarios. A questionnaire was applied to 66 sheep farmers on technical variables, flock management, economic and social aspects. Two scenarios were analyzed to assess the contribution of grazing on profitability and competitiveness. The first analysis was when grazing was the feed base, and secondly, costs of opportunity and economic impacts were studied under the assumption that sheep do not graze and total feed has to be bought from feed vendors. In order to determine the differences between the farmers with the highest and lowest profitability indexes, a four-stratum stratification was made (stratum 1, between 6 and 35 sheep; stratum 2, 36 to 70 sheep, stratum 3 = 71 - 105 sheep; and stratum 4, 106 to 140 sheep). Quantitative variables (technical management, flock management and social aspects) were evaluated with analysis of variance, while qualitative variables were analyzed by means of a Kruskal-Wallis test. Production cost analysis and profitability index were assessed with the Policy Analysis Matrix. Differences were found between strata, farmers with more than 70 sheep have the best profitability indices and the least vulnerability before the non-grazing scenario. Grazing had a positive effect reducing the cost of production and increasing competitiveness in the four strata assessed. However, farmers with higher technical level, specialized breeds and larger flocks (strata 3 and 4) have higher economic profits.

Introduction

A global population of 8.5 billion people is expected by 2030 (UN 2019) that will increase the demand for food (Fukase and Martin 2020), and the need to devise new strategies and economic policies that enable potentiating the production of food from animal origin and maximizing the use of natural resources, ensuring thus food security and poverty reduction (Brander et al. 2021).

In this scenario, contributions from small-scale agriculture are preponderant in the local food supply and food sovereignty despite facing increasingly greater challenges, including emergent infectious diseases such as Covid-19 (Guiomar et al. 2018; IFAD 2021).

In the agricultural sector, sheep production contributes to the global food supply due to its multifunctional role in meat, wool and dairy production (Pulina et al. 2018; Zygoyiannis 2006). Particularly, Small-scale Sheep Production Systems (SSSPS) stand out because they are located in geographic areas with challenging agro-ecological conditions, where implementing production systems of other livestock species is difficult.

In Mexico, SSSPS have one of the best profitability rates and growth prospects in the livestock sector (Martínez-González et al. 2011) since their characteristics enable them to turn by-products and residues from unprofitable harvests into useful human food with high nutritional and economic value (Wilkinson 2011; Herrera et al. 2019). SSSPS are mostly located in states of central Mexico, which provide 35% of national production (SIAP 2019); and the region consumes 85% of the national demand (Rodríguez-Licea et al. 2016).

The state of Hidalgo is the second national producer of sheep meat at national level, which takes place mostly in 84 municipalities, of which Singuilucan (the study area) holds the first national place contributing with 7% of the total sheep production (SIAP 2019).

Out of the livestock activities developed in Singuilucan, sheep production is one of the most profitable and competitive (INEGI 2017) because it is mainly developed under an extensive production system that allows farmers to reduce production costs and have a better cost / benefit ratio than intensive (confined flocks) production systems (Partida de la Peña et al. 2013; Ripoll-Bosch et al. 2014), a condition that is increased by the demand of unfulfilled markets, e.g., meat for *barbacoa* (a traditional oven baked dish of sheep meat) with high sale prices for finished sheep, and insufficient domestic production. These factors position this activity as one of the most economically attractive in the region under study.

In this scenario, research on the contribution of grazing to the profitability and competitiveness of SSSPS may lead to useful information for decision makers at the farm level, mainly in a context with little scientific research on this production system in central Mexico.

The in-depth study of particular production systems does have implications for other livestock systems in a broader international context, both in the issues studied in detail as in terms of the methodologies applied.

There are various methodologies to assess profitability and competitiveness supported on economic theory; as the Policy Analysis Matrix (PAM). It is one of the most utilized in the agricultural sector (Salcedo 2007) because it enables the analysis of production efficiency, comparative advantages and impacts from economic policies on the assessed production system (Posadas-Domínguez et al. 2018) and as a result, it produces simple data that may be used by farmers to support their financial decisions and improve the administration of their businesses.

In this context, the objective of the present study was to assess the economic advantages from grazing on the profitability and competitiveness of a small-scale sheep production system in central Mexico by means of an analysis of scenarios.

Materials And Methods

Study area

The study was carried out in Singuilucan, a municipality in the state of Hidalgo, Mexico. It is located in the southeast of the state at 19° 58' 03" North and 98° 31' 02" West, at an altitude of 2,400 – 3,100 m. Climate is temperate sub humid with rainfall from 500 to 800 mm/year and a rainy season from May to September. The territorial extension of the municipality of Singuilucan is 420 km², of which 66% is destined for agricultural activities such as maize, barley, oat, forage, green alfalfa and grazing pastures that allow developing sheep, cow and goat production systems as the most important due to their economic contribution (INEGI 2017).

General description of the sheep system

SSSPS in the region under analysis may be characterized as farms with flocks from 3 to 150 sheep in three modes of production: 1). Farms specialized in breeding flocks where the main objective is the sale of weaned lambs for further fattening and finishing, 2). Full-cycle farms devoted to breeding, fattening and finishing of sheep for the market, and 3). Farms devoted to fattening and finishing sheep bought from the breeding farms and sold to the meat market for *barbacoa*.

In the study area, 85% of sheep production is under this latter production orientation, so that this research was focused on the sheep fattening farms by the analyses of economic indicators according to their particular production characteristics of low technology adoption and production undertaken mainly in a backyard system basing feeding on grazing and crop by-products. The backyard system refers to the keeping of flocks in an improvised area of the farm not specifically designed for sheep production, nor with specific infrastructure for the flock.

The workforce is largely family labour. The flock breed is mainly Hampshire and crosses with Suffolk, Dorper, Dorset and mixed-breed sheep, almost totally sold as meat for *barbacoa* a traditional oven roasted dish (Vélez et al. 2016), with a sale price of 2.65 USD\$ per kilogram live sheep on the hoof at the time of this research.

Analyses of scenarios

The present study considered two phases; in the first, the technical and economic characteristics of the farms were described; in the second, the impact of these characteristics on production costs, profitability and competitiveness was assessed. To meet this, two scenarios were analyzed; in the first, the structure of costs was evaluated with a view to analyze the current profitability level and the comparative advantage grazing has in the studied sheep production systems; and in the second, opportunity costs and the assessment of the economic impact of losing the advantage of grazing simulating the purchase of 100% of feed from local or regional forage traders were studied.

The monetary values used in this research were in Mexican pesos (MXN) and converted to US dollars (USD\$) at an exchange rate of 18.80 MXN per one USD\$ (data from Banco de México on January 15th, 2020).

Statistical sample

A statistical representative sample was selected from 1,000 SSSPS registered in livestock associations in the municipality. Following the method proposed by Aguilar-Barojas (2005), 25 pilot interviews were held, identifying heterogeneity in the results among the systems for the technical and economic variables of interest. A stratified random sampling with proportional stratifications was carried out after these results (Cochran 1977). The calculation of the sample size considered the number of head in production as stratification criterion and was based on a 3-percent estimator accuracy at a confidence level of 95%. A sample of 66 farms allotted in four strata: stratum 1, from 6 to 35 head; stratum 2, 36 to 70 sheep; stratum 3, 71 – 105 head; and stratum 4, farms with 106 to 140 sheep (Table 1). To define the sample size the following formulae were used:

$$n_0 = \frac{Z_{1-\frac{\alpha}{2}}^2}{d_0} \sum_{i=1}^k W_i * S_i^2$$

$$n_i = n * W_i \text{ where } W_i = \frac{N_i}{N} \quad \forall i = 1, 2, \dots, k$$

Where: $n_0 = \frac{Z_{1-\frac{\alpha}{2}}^2}{d_0}$ = confidence level; W_i = weight for each stratum; S_i^2 = Variance; d_0 = estimator accuracy; and, n_i = sample size at the i-nth stratum.

Please insert Table 1 here

Collection of information

Information in the field was obtained by means of the procedure proposed by Herrera et al. (2019), based on information on technical variables from direct interviews with the farmers to describe production processes, flock management, and economic aspects to determine the profitability of farms and social aspects related to the farmers' family. The information was obtained and updated by means of visits and telephone calls with the farmers between July 2017 and August 2019.

Statistical analyses

The Statistical Package for the Social Sciences (SPSS) v.25 was utilized to analyze the information gathered in the field. The average value and standard deviations were calculated applying descriptive statistics, with which the general characteristics of the farms were analyzed, namely: technical management, flock management and social aspects (first phase). The normal distribution of the data was verified with the Shapiro-Wilk test; variables with non-normal distribution were analyzed with their median value. The assessment of the effect of stratum on continuous quantitative variables with normal distribution was by means of a one-factor analysis of variance (ANOVA), when there were differences between strata, a comparison of means was with a Tukey test ($P \leq 0.05$). Qualitative variables or with non-normal distribution were analysed with the nonparametric Kruskal-Wallis test, and when there were differences between strata, the mean comparison was by the K-sample median test.

Economic analysis

The second phase of the work was the analysis of the impact that technical and economic characteristics have on profitability and competitiveness, which were evaluated by means of a PAM. According to Monke and Pearson (1989), a PAM may be utilized as a tool to measure efficiency in the use of inputs,

comparative advantages and the degree of government interventions. The first item of this methodology defines private profitability as the difference between incomes and mean costs at market prices (first row); whereas the second measures the effects of the differences in incomes, costs and profits that come from distorted policies and market flaws (Salcedo 2007).

Measures of profitability and competitiveness

Private returns

The first row of a PAM measures private profitability and competitiveness of the agricultural system considering current technologies, input prices, production level and the commercial policy in force (Monke and Pearson 1989). By private, it is understood the observed incomes and costs that reflect the actual market prices received or paid by the farmers or merchants in the agricultural system. Private profit is calculated in the first row of the matrix, and it is the difference between private profits and costs valued at market prices (private values). This way, positive private returns indicate competitiveness, while negative ones mean that the system is not competitive; this way, it is expectable that farmers drop this activity (Rebollar-Rebollar et al. 2011):

$$D = A - (B + C)$$

Where: D = private returns; A = private incomes, B = cost of commercial supplies at private price; C = costs of internal factors.

Private profitability may be assessed by means of the following concepts in a spreadsheet: a) marketable supplies, this section considers all the supplies that are marketable in commercial aperture conditions and are internationally wanted such as food, medicine, fuel, seeds, among others; b) internal factors, this concept comprises all the components of the costs and expenditures related to production, though they cannot be internationally traded, owing to this their price is defined by the free offer and demand in the internal market. At this level the following concepts are assessed: labour force, land hiring, and the depreciation of the facilities, among others; and c) total incomes, which are evaluated considering the final sale price of the product in the market. For this study, the final sale price of each finalized sheep in the market was 2.66 USD\$ per kg live weight on the hoof at the time of this research. The components above may be summarized in the structure of PAM (Table 2).

Please insert Table 2 here

Indicators of economic efficiency

The PAM methodology has a number of indicators of economic efficiency utilized to measure the profitability and competitiveness at private and social prices. For the present study, the profitability and competitiveness of SSPPS were assessed from the indicators in the first row of PAM (Monke and Pearson 1989; Posadas-Dominguez et al. 2018; Rebollar-Rebollar et al. 2011).

Private profitability ratio (PPR)

this indicator measures the profitability of the producer or farm per dollar invested. In order to calculate it, the ratio of private gain is divided between the addition of marketable supplies and internal factors.

$$PPR = \left[\frac{D}{(B+C)} \right]$$

Private cost ratio (PCR). It estimates private efficiency from an economic analysis that allows finding out how much of the internal factors the farmers are capable of paying and from this calculation the competitiveness of the system is determined.

$$PCR = \frac{\sum_{j=k+1}^n P_k^P}{P_i^P \sum_{j=1}^k a_{ij} P_j^P} = \frac{C}{A-B}$$

Where: a_{ij} for $(j = 1 \text{ up to } k)$ = technical coefficient for the marketable supplies utilized in sheep production; a_{ij} for $(j = k + 1 \text{ up to } n)$ = technical coefficient for the internal factors used in sheep production; P_i^P = sale price per kilogram of live sheep privately evaluated; P_j^P = price of marketable supplies in sheep production privately evaluated; P_k^P = price of internal factors in sheep production privately assessed; A = private income; B = cost of marketable inputs at private price; C = cost of internal factors.

The estimation of PCR is the test that measures competitiveness level and its results may be interpreted as follows: if $PCR < 1$, the production system is competitive and has extraordinary profits, in such manner that values closer to zero will express greater competitiveness; if $PCR = 1$, no extraordinary profits are earned, it is the balance point of the system; finally, if $PCR > 1$, the production system will not be competitive as it cannot generate sufficient economic benefits to afford the production factors.

Results

Main characteristics of the farms

Table 3 shows there were no significant differences in the variables: farm owner, age, schooling level, and time as farmers; though, farmers in stratum 2 hold higher schooling and time farming. Farmers in strata 1 and 2 were the ones with the least sheep in finalization (fattening) as compared with farmers in strata

3 and 4. It was observed that all the farmers favor fattening Hampshire sheep instead of mixed breeds. The backyard system is the prevailing form of production in the four strata assessed, although farmers in stratum 4 tend to have more specialized management.

Please insert Table 3 here

Technical and economic indicators

The significance tests of technical and economic indicators by stratum are shown in Table 4. There were no differences between strata for sheep sales, which is mainly carried out in the meat market for *barbacoa*. The prevailing production system in the four strata is based on grazing. The farm is the only income source for more than 55% of the participant farmers; a higher dependency is noticed for farmers in strata 3 and 4, nevertheless. No significant differences were found between strata for sheep supplementation and labour use, which is mainly family members. The participation of wives in farming activities is an important element in the four strata of farmers evaluated; however, their participation is higher in strata 3 and 4, associated to greater labour needs due to the size of the farms.

Please insert Table 4 here

Production cost

Table 5 shows the costs of production by the stratification level of sheep farms. The marketable supplies per finalized (fattened) sheep account for more than 86% of the total production cost at the four scales of farms assessed. In this regard, acquiring the sheep and feeding them entail the heaviest investment for each stratum as they account for 80% percent of the total cost. Albeit, it is observed that feeding cost was 3.00 USD\$ higher for strata 1 and 2 when compared with strata 3 and 4, which indicates higher efficiency in cost reduction as the flock size increases. The services farms use (i.e., water and electricity) as well as workforce account for the highest cost as regards the production factors for each stratum. It may be noticed, nevertheless, that farmers in strata 1 and 3 hire a larger number of people than farmers in strata 2 and 4.

Please insert Table 5 here

Net costs and benefits with and without grazing

A scale effect is observed in Figure 1 for cost of production with and without grazing, which translates as a lower cost for strata with a larger number of finalizing sheep (strata 3 and 4). The scenario without grazing increases cost per finalized sheep in about 22 USD\$; net profit is 20 USD\$ higher when farmers base feeding on grazing, as compared with profit per sheep when simulating the purchase of feed from local and regional forage sellers.

Please insert Fig. 1 here

Private profitability and competitiveness indicators

Private profitability ratio (PPR)

Table 6 shows that for both scenarios, with and without grazing, private profitability was higher for farmers in strata 3 and 4, regardless of the investment in each stratum. The results indicate that if the current production schema, based on traditional grazing, changes to buying feed from local and regional sellers (scenario without grazing), per-dollar profitability would drop 0.33 and 0.35 USD\$ for farmers in strata 1 and 2, while 0.37 and 0.40 USD\$ for farmers in strata 3 and 4.

Private cost ratio (PCR)

Financially, the business of producing sheep in the grazing scenario offers an attractive investment alternative for small-scale sheep farmers owing to the observed competitiveness level with more than 70 head in production (strata 3 and 4), considering the investment returns that might be obtained, which otherwise would be hardly earnable from a different investment opportunity. Albeit by simulating the purchase of feed from local and regional sellers (scenario without grazing), the results display a competitiveness reduction of 75% and 79% for farmers in strata 1 and 2; and 59% and 57% for farmers in strata 3 and 4 (Table 6).

Please insert Table 6 here

Discussion

Main characteristics of the farms

The farmers in the four strata assessed are 80% men (Tindano et al. 2015; Vélez et al. 2016) aged on average between 53 and 65 years old (Marín-Bernal and Navarro-Ríos 2014; Morales et al. 2004; Galaviz-Rodríguez et al. 2011; Lima et al. 2018). The experience in the activity, measured in years, was not statistically significant between strata, however, the average (6 years) was lower than that reported in various research works on small-scale sheep systems (Nuncio-Ochoa et al. 2004; Vélez et al. 2016; Marín-Bernal and Navarro-Ríos 2014; Salamanca et al. 2018).

Among other reasons, this may be explained by the constant generational replacement in the study area as sheep production is an economically attractive activity for new generations and since the region has 61% poverty and a 25% of schooling deficit (CONEVAL 2020), this turns into one of their best employment options keeping the family together with no need for migration to cities nearby.

On the basis of the results, SSSPS may be considered viable alternatives to decrease migration and poverty indexes in the study area and in rural populations with similar characteristics where small-scale sheep production is carried out.

Among the factors reported in the literature to maintain an agricultural system running, one finds education level. For the present study, this variable ranged between incomplete and complete elementary school (4-6 schooling years) that is lower than reports for other sheep producing regions in Mexico (Herrera et al. 2019), and lower than the international mean (Tindano et al. 2015; Voors and Haese 2010).

This characteristic may be a variable that conditions the potential of SSSPS in the near future, as it was demonstrated that at a higher education level enables the farmers to increase technology adoption (Martínez-García et al. 2015; Martínez-García et al. 2016), which consequently produces higher economic benefits and ensures the permanence of the system.

In this scenario, the assessed SSSPS could improve its economic conditions through a higher education level; though this variable does not only depends on the farmers, but also on the socioeconomic context of the state, which implies a great challenge for Mexican public policies, which by means of various government agencies provide the farmers with education that should be aimed at their needs, particularly focused on training and strengthening the technical management of their farms, rather than on traditional literacy programs.

The four strata analyzed have a clear tendency to use the Hampshire sheep breed in their farms. Cruz-Colín et al. (2006) reported that in central Mexico, Hampshire lambs have proven superiority over Suffolk and Dorset ones regarding characteristics such as daily weight gain and feed conversion. It may be a factor that explains all the farmers' preference for the Hampshire breed, for it relates to a shorter fattening time and lower production costs, which increase the financial success of the farms (Ramírez-Tello et al. 2013).

However, the advantage offered by improved breeds is not capitalized if the production system uses little technology and technical training (Martínez-Peña et al. 2018). Probably farmers in strata 1, 2 and 3 are in this scenario as they have lower schooling, years in the activity and finalize about 80% of the sheep under the backyard system. This suggests low technology adoption and technical training as compared with farmers in stratum 4, who only finalize 45% of their production under the backyard system, whereas the other 65% is via a semi-technified production system.

Technical and economic indicators

The main commercialization channel of SSSPS in the central states of Mexico is farmer-middleman and farmer- meat market for *barbacoa* with low percentage profit at the sale for end consumers and self-consumption (Vélez et al. 2016; Herrera et al. 2019). Though this commercialization scheme has advantages for the farmers, since they accept fixed sale prices set by the middlemen by negotiating their prices on a farmer-by-farmer basis (Kocho et al. 2011). These are on occasions the only possibility for trade due to the limitations in mobilizing animals, as well as savings on the transport costs of finalized sheep to the markets for sale (Martínez-Peña et al. 2018; Hernández-Martínez et al. 2013).

However, this scenario is financially balanced by the conditions of the Mexican market in the central states, including the study area, characterized by an important tradition oriented to *barbacoa* as a local dish, for the weekends, with a high and competitive price for the farmers (Vélez et al. 2016). The above is a determining factor to explain the farmer-market commercialization channel observed in the four strata assessed, under which they virtually sell 100% of the finished sheep.

Sheep production in the four strata is based on a traditional grazing system. This production strategy is utilized because the natural areas of the study area offer vast land extensions with inexpensive renewable resources for grazing (De Rancourt et al. 2006). Consequently, the benefits for the sheep system assessed mean an advantage due to the constant fluctuations in the prices of feed supplies (Ripoll-Bosch et al. 2014; Dorward 2013) observed at the local feed stores. The forage resources, including native grasslands, cultivated pastures and crop residues are some of the best options to increase the profitability of sheep systems from the financial standpoint (Morantes et al. 2017; Martínez-González et al. 2011), as it has been demonstrated that grazing considerably reduces production costs and facilitates the management of sheep farms (Marín-Bernal and Navarro-Ríos 2014).

Labour in the evaluated SSSPS is preponderantly family, mainly in farms with six to 70 sheep in finalization (strata 1 and 2); a scenario that has potential to increase the production of the four assessed strata. The above, supported on the specialization of labour as knowledge capital, is one of the precursors to attain economies of scale; though, agricultural labour is underrated. Therefore, it is important that new public policies recognize their potential so that governments and firms invest on this production system (Dorward 2013). This characteristic is relevant if we consider small-scale agricultural production has supported its permanence and profitability on the intensive use of family labour (Posadas-Domínguez et al. 2018; Salinas-Martínez et al. 2020), owing to which a higher specialization would allow SSSPS continue contributing to the total production of sheep meat in Mexico, generating food and employment sources.

Production costs

One of the main characteristics that define SSSPS in the study region is low financial and economic management. This particularity may lead to deficient cost control, as farmers do not see their farms as a business, therefore they overlook investment plans, profit margins and other important economic indicators (Marques et al. 2011).

In the present research it was observed that farmers in strata 1, 2 and 3 keep their accounting in an empirical manner, while only some farmers in stratum 4 keep their basic balances in a notebook. Lu et al. (2016) mentioned that a possible explanation for the poor administration of family farms may be associated to the fact that authority and decision-making fall on a single person, this way, the use of accounting techniques for control becomes less necessary (Ndemewah et al. 2019).

This behaviour was verified in this study for the four strata assessed by noticing that the farmer and household head, generally a man, is responsible for decision making and farm management.

In this context, the present research was carried out for the purpose of producing information useful for the farmers; however, the results show the accounting of SSSPS at a single point in time and for administrative management to be efficient, higher economic investment and governmental support are necessary to develop an accounting system suitable for the needs of small sheep farmers. This system has to be easy to access and implement into the daily activities of the farmers, in such manner that the system becomes able to have control over incomes and expenditures in real time, similar to any other firm, on the contrary, in the best of cases decisions will be made on the basis of past information that may not account for the financial performance of the sheep system.

In the four strata, grazing accounts for the second highest production price, owing to which its impact on the financial structure is significant. The results of this research indicate higher efficiency in farmers in strata 3 and 4, as compared with farmers in strata 1 and 2. This may be explained by the larger number of finalizing sheep (Theodoridis et al. 2012), which allows farmers in the former strata to negotiate lower prices in the hiring of grazing, stubbles, fallows and communal pastures (Olaizola et al. 2008; Riveiro et al. 2013; Salamanca et al. 2018), closing deals mostly on their word with the owners. This is something that farmers in strata 1 and 2 cannot always accomplish, as they need smaller pastures and this rises the price and thereby, production costs also increase.

Expenditures on services such as water and electricity bills and hired labour are the highest costs in the production factors for the four strata assessed; however, it is important to underscore that for farmers in stratum 1 the highest production cost was hiring workforce in comparison with farmers in strata 2, 3 and 4. This may be explained by a heavier dependency on external income (44%) observed for farmers in stratum 1. Among other variables, this characteristic demands pluri-activity (Vértiz 2016) in paid non-agricultural work to complement their incomes (Alvarado et al. 2011; Estevez-Moreno et al. 2019); mainly, as construction workers, taxi drivers or salespeople.

Results showed that at a farm size of 71-140 finalizing sheep, the cost of marketable supplies and production factors are optimal, and farms become a business with greater economic profits.

Net costs and benefits with and without grazing

In the study, by means of simulating scenarios, it was observed that feeding based on grazing reduces production costs (Miller et al. 2015) in about 22 USD\$ in each assessed stratum, which allows increasing profits per sheep in about 20 USD\$, as compared with profits simulating the purchase of feed from local and regional sellers. Similar results were reported by González-Garduño et al. (2013), who noticed a 35-percent reduction in the cost of production and a higher revenue per kilogram gained when sheep in small-scale systems are grazed.

An additional advantage observed in the study when farmers resort to grazing as feeding strategy is the lower volatility they face as regards the price of this input (Olaizola et al. 2008), on which farmers have a better negotiation leverage since it is not regulated by a market, as compared with feed purchased from local or regional sellers, where prices are subject to fluctuations and farmers have to accept that prices are defined by offer and demand. In this panorama, grazing is a determining factor that allows SSSPS towards sustainable production, as they utilize the most inexpensive feed in sheep farms (Finneran et al. 2010).

In a production plan based on grazing, demographic growth is a constant threat against SSSPS, since urbanization has a high demand for land and massively uses natural resources (Deng et al. 2008; Alcañiz 2008), which might pose a problem for sheep production. Although this region is presently considered rural and 66% of the land is engaged in agricultural activities (INEGI 2017), sheep farmers have to especially take care of the grazing lands as this variable provides them with a competitive advantage that means a 20-American-dollar gain per finalized sheep over the simulated scenario without grazing.

Indicators of profitability and private competitiveness

Private profitability ratio (PPR)

It has been demonstrated that production based on grazing is a key driver to increase the profitability of sheep production systems (Bohan et al. 2018). This was observed in this research, as there was a higher profitability in all the strata assessed when grazing is the feed base (Ripoll-Bosch et al. 2014), in comparison with the simulation of the purchase of feed from local and regional sellers.

González-Garduño et al. (2013) agreed with these results as they reported a private profitability 132% greater when sheep are grazed as compared with a negative profitability (-12.30%) when animals are offered commercial feed. These results verify the importance grazing has on small-scale sheep production profitability, particularly in this study for the four strata assessed, grazing means the main difference between low- and high-profitability farmers.

The results of the present study indicate that farmers in strata 3 and 4 have the best financial performance per dollar invested in the four strata evaluated, that may be explained mainly by a wider technology adoption, as the use of specialized breeds (Hampshire) with better feed conversion (Cruz-Colín et al. 2006), and also a larger flock size.

These characteristics offer advantages in terms of profitability over farmers in strata 1 and 2. However, farmers in strata 3 and 4 still need to substantially increase their use of technology in order to compete with international sheep systems in terms of profitability (Toro-Mujica et al. 2011). Provided these conditions, it is considered that the assessment of these production systems may increase their efficiency if new technologies are set up to optimize the available grazing resources (Gaspar et al. 2008), which would become an increment in financial viability (Rivas et al. 2019) and economic benefits.

Private cost ratio (PCR)

Financially, making business in sheep production in the region under study in the grazing scenario offers an attractive investment option for it has rates of return per invested USD\$ over 50% in short 4-month cycles; this financial performance would be hardly obtained with a different investment alternative. In spite of these results, the evaluated farmers do not see their farm as a firm, therefore they disregard investment plans, which leads to loss of competitiveness (Marques et al. 2011), mainly in production systems with flock size fewer than 70 finalizing sheep (strata 1 and 2), and they see their farms as tradition or family savings, not as revenue generators (Marques et al. 2011) that enable them to make their living out of this activity.

The present study identified that a change in the production plan based on traditional grazing to another based on buying feed from local or regional sources (scenario without grazing) would decrease competitiveness more than 50% in the four strata, though with a stronger effect for farmers in strata 1 and 2, due mainly in these strata by poor adoption of technology, use of mixed breeds and smaller flock size.

Similar results were reported by Toro-Mujica et al. (2011), who concluded that the competitiveness of the sheep system is higher when the production scale is increased in terms of livestock, while the feed base is organized in function of grass availability or seasonal forages and local agricultural byproducts, which translates as a significant profitability increment (Bohan et al. 2018). This was observed in the four strata assessed, which according to their technology level and technical management capacity of grazing in free zones and use of agricultural byproducts reduced their production costs and increased their competitiveness. However, the advantage that grazing offers may be better harnessed if farmers implement new management technologies.

The results of the present study identified differences between the sheep farms evaluated. These differences were mainly associated to technology level, specialized breeds and farm size. Flocks with more than 70 sheep in production and that focus their economic resources on increasing technology level have the highest profitability index as well as the lowest vulnerability if they lose grazing. The analysis of scenarios allowed identifying a positive effect of grazing on production costs and competitiveness in the four strata assessed; however, the economic benefits increased when farmers had more technology, specialized breeds and number of sheep. With these results, it is concluded that sheep profitability is associated with the harnessing of grazing, specialized breeds and flock size, owing to this, in order to maintain it, the simultaneous application of integral strategies for the improvement of the flocks and the appropriation of new nutritional technologies to manage grazing to jointly allow the reduction of production costs are suggested.

Results and the methodology used in this study may be applied to small-scale production systems in other latitudes as it enables the integral assessment of the economic incomes of financial assets that allow the economic benefits to increase.

Declarations

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Conflicts of interest/Competing interests

The authors declare that they have no conflict of interest.

Ethics approval

Work with the collaborating farmers followed guidelines accepted by Instituto de Ciencias Agropecuarias of Universidad Autónoma del Estado de Hidalgo.

Consent to participate

Collaborating small-scale sheep farmers were duly informed and were fully aware of the objectives of the work agreeing to participate in the study, and their privacy and that of their families is respected by not disclosing their names.

Consent for publication

Not applicable.

Availability of data and material (data transparency)

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability (software application or custom code)

Not applicable.

Author contribution

Jesús Armando Salinas-Martínez, Rodolfo Rogelio Posadas-Domínguez, Carlos Manuel Arriaga-Jordan - Conceptualisation

Rodolfo Rogelio Posadas-Domínguez, Juan Carlos Ángeles-Hernández – methodology; Jesús Armando Salinas-Martínez, Rodolfo Rogelio Posadas-Domínguez - formal analysis and investigation;

Rodolfo Rogelio Posadas-Domínguez, Juan Carlos Ángeles-Hernández, Jesús Armando Salinas-Martínez, Leydi Diana Morales-Díaz, Samuel Rebollar-Rebollar, Rolando Rojo-Rubio - writing — original draft;

Carlos Manuel Arriaga-Jordan, Juan Carlos Ángeles-Hernández - writing — review and editing.

All authors read and approved the final manuscript.

References

1. Aguilar-Barojas S., 2005. Fórmulas para el cálculo de la muestra en investigaciones de salud. *Salud en Tabasco* 11, 333–338. Available from: <http://www.redalyc.org/articulo.oa?id=48711206> (accessed 21 November 2020)
2. Alcañiz, M., 2008. Cambios demográficos en la sociedad global. *Papeles Población* 227–254
3. Alvarado, M.M.C., Juárez, S.J.P., Ramírez V.B., Ramírez, J.J., 2011. Empleo rural no agrícola en la comunidad de San Mateo Ayecac, Estado de Tlaxcala, México. *Papeles de Geografía* 53, 21-33
4. Bohan, A., Shalloo, L., Creighton, P., Earle, E., Boland, T.M., Mchugh, N., 2018. Investigating the role of stocking rate and prolificacy potential on profitability of grass based sheep production systems. *Livest. Sci.* 210, 118–124. <https://doi.org/10.1016/j.livsci.2018.02.009>
5. Brander, M., Bernauer, T., Huss, M., 2021. Improved on-farm storage reduces seasonal food insecurity of smallholder farmer households – Evidence from a randomized control trial in Tanzania. *Food Policy* 98. <https://doi.org/10.1016/j.foodpol.2020.101891>
6. Carrera, C.B., Carrera, C.J.M., 2011. Características de la producción ovina en el municipio de Pinos, Zacatecas: el municipio con mayor inventario nacional. *innovación de procesos en la producción de carne de ovino en Zacatecas. Reporte técnico de investigación*. Available from: <https://es.scribd.com/document/416134098/3-Caracteristicas-Produccion-Ovina> (accessed 23 October 2020)
7. Cochran, W.G., 1977. *Sampling Techniques*, Tercera Edición. John Wiley & Sons, Inc, pp. 428
8. CONEVAL. Consejo Nacional de Evaluación de la Política de Desarrollo Social. 2020. Pobreza a nivel municipio. Available from: [2015https://www.coneval.org.mx/coordinacion/entidades/Hidalgo/Paginas/pobreza_municipal2015.aspx](https://www.coneval.org.mx/coordinacion/entidades/Hidalgo/Paginas/pobreza_municipal2015.aspx) (accessed 15 March 2020)
9. Cruz-Colín, L., Torres-Hernández, G., Nuñez-Domínguez, R., Becerril-Pérez, C.M., 2006. Evaluation of productive traits of hampshire, dorset and suffolk lambs in performance testing, at hidalgo, México. *Agrociencia Méx* 40, 50–59
10. De Rancourt, M., Fois, N., Lavín, M.P., Tchakérian, E., Vallerand, F., 2006. Mediterranean sheep and goats production: An uncertain future. *Small Rumin. Res.* 62, 167–179. <https://doi.org/10.1016/j.smallrumres.2005.08.012>
11. Deng, X., Huang, J., Rozelle, S., Uchida, E., 2008. Growth, population and industrialization, and urban land expansion of China. *J. Urban Econ.* 63, 96–115. <https://doi.org/10.1016/j.jue.2006.12.006>
12. Dorward, A., 2013. Agricultural labour productivity, food prices and sustainable development impacts and indicators. *Food Policy* 39, 40–50. <https://doi.org/10.1016/j.foodpol.2012.12.003>
13. Estevez-Moreno, L.X., Sanchez-Vera, E., Nava-Bernal, G., Estrada-Flores, J.G., Gomez-Demetrio, W., Sepúlveda, W.S., 2019. The role of sheep production in the livelihoods of Mexican smallholders: Evidence from a park-adjacent community. *Small Rumin. Res.* 178, 94–101. <https://doi.org/10.1016/j.smallrumres.2019.08.001>
14. Finneran, E., Crosson, P., O'Kiely, P., Shalloo, L., Forristal, D., Wallace, M., 2010. Simulation modelling of the cost of producing and utilising feeds for ruminants on Irish farms. *J. farm Manag.* 14, 95–116.
15. FAO. Food Alimentation Organization of the United Nations. 2017. El estado mundial de la agricultura y alimentación. Aprovechar los sistemas alimentarios para lograr una transformación rural inclusiva. Available from: <https://reliefweb.int/report/world/el-estado-mundial-de-la-agricultura-y-la-alimentacion-2017-aprovechar-los-sistemas> (accessed 11 December 2020)
16. FAO. Food Alimentation Organization of the United Nations. 2019. Ganadería sostenible y cambio climático en América Latina y el Caribe. Available from: <http://www.fao.org/americas/prioridades/ganaderia-sostenible/es/> (accessed 15 September 2019)
17. Fukase, E., Martin, W., 2020. Economic growth, convergence, and world food demand and supply. *World Dev.* 132. <https://doi.org/10.1016/j.worlddev.2020.104954>
18. Galaviz-Rodríguez, J.R., Vargas-López, S., Zaragoza-Ramírez, J.L., Bustamante-González, A., Ramírez-Bribiesca, E., Guerrero-Rodríguez, J de D., Hernández-Zepeda, J.S., 2011. Evaluación territorial de los sistemas de producción ovina en la región nor-poniente de Tlaxcala. *Rev. Mex. Ciencias Pecu.* 2, 53–68.
19. Gaspar, P., Escribano, M., Mesías, F.J., Ledesma, A.R. de, Pulido, F., 2008. Sheep farms in the Spanish rangelands (dehesas): Typologies according to livestock management and economic indicators. *Small Rumin. Res.* 74, 52–63. <https://doi.org/10.1016/j.smallrumres.2007.03.013>
20. González-Garduño, R., Blardony-Ricardez, K., Ramos-Juárez, J.A., Ramírez-Hernández, B., Sosa, R., Gaona-Ponce, M., 2013. Rentabilidad de la producción de carne de ovinos Katahdin x Pelibuey con tres tipos de alimentación. *Avan. en Invest. Agro.* 1, 135–148
21. Guiomar, N., Godinho, S., Pinto-Correia, T., Almeida, M., Bartolini, F., Bezák, P., Biró, M., Bjørkhaug, H., Bojnec, Brunori, G., Corazzin, M., Czekaj, M., Davidova, S., Kania, J., Kristensen, S., Marraccini, E., Molnár, Z., Niedermayr, J., O'Rourke, E., Ortiz-Miranda, D., Redman, M., Sipiläinen, T., Sooväli-Sepping, H., Šūmane, S., Surová, D., Sutherland, L.A., Tcherkezova, E., Tisenkopfs, T., Tsiligiridis, T., Tudor, M.M., Wagner, K., Wästfelt, A., 2018. Typology and distribution of small farms in Europe: Towards a better picture. *Land use policy* 75, 784–798. <https://doi.org/10.1016/j.landusepol.2018.04.012>

22. Hernández-Martínez, J., Ortíz-Rivera, M.I., Rebollar-Rebollar, S., Guzmán-Soria, E., González-Razo, F.D.J., 2013. Comercialización de ovinos de pelo en los municipios de Tejupilco y Amatepec del Estado de México. *Agron. Mesoam.* 24, 195–201. <https://doi.org/10.15517/am.v24i1.9798>
23. Herrera, H.J.G., Alvarez, F.G., Bárcena, G.R., Núñez, A.J.M., 2019. Caracterización de los rebaños ovinos en el sur de Ciudad de México, México. *Acta Univ.* 29, 1–15. <https://doi.org/10.15174/au.2019.2022>
24. INEGI. Instituto Nacional de Estadística y Geografía. 2017. Anuario estadístico y geográfico de Hidalgo 2017. Available from: http://internet.contenidos.inegi.org.mx/contenidos/Productos/prod_serv/contenidos/espanol/bvinegi/productos/nueva_estruc/anuarios_2017/70282509 (accessed 28 November 2020)
25. Kocho, T., Abebe, G., Tegegne, A., Gebremedhin, B., 2011. Marketing value-chain of smallholder sheep and goats in crop-livestock mixed farming system of Alaba, Southern Ethiopia. *Small Rumin. Res.* 96, 101–105. <https://doi.org/10.1016/j.smallrumres.2011.01.008>
26. Lima, E., Hopkins, T., Gurney, E., Shortall, O., Lovatt, F., Davies, P., Williamson, G., Kaler, J., 2018. Drivers for precision livestock technology adoption: A study of factors associated with adoption of electronic identification technology by commercial sheep farmers in England and Wales. *PLoS ONE* 13, 1–17. <https://doi.org/10.1371/journal.pone.0190489> WOS41 Si006 1–17.
27. Lu, C., Sridharan, V.G., Tse, M.S.C., 2016. Implementation of the Activity-Based Costing Model for a Farm: An Australian Case. *J. Appl. Manag. Account. Res.* 14, 29–36.
28. Marín-Bernal, A.M., Navarro-Ríos, M.J., 2014. Análisis y diagnóstico de los sistemas de producción ovina en el sureste Español. *Arch. Zootec.* 63, 519–529. <https://doi.org/10.21071/az.v63i243.531>
29. Marques, P.R., Barcellos, J.O.J., McManus, C., Oaigen, R.P., Collares, F.C., Canozzi, M.E.A., Lampert, V.N., 2011. Competitiveness of beef farming in Rio Grande do Sul State, Brazil. *Agric. Syst.* 104, 689–693. <https://doi.org/10.1016/j.agsy.2011.08.002>
30. Martínez-García, C.G., Dorward, P., Rehman, T., 2016. Factors influencing adoption of crop and forage related and animal husbandry technologies by small-scale dairy farmers in Central México. *Exp. Agric.* 52, 87–109. <https://doi.org/10.1017/s001447971400057x>
31. Martínez-García, C.G., Ugoretz, S.J., Arriaga-Jordán, C.M., Wattiaux, M.A., 2015. Farm, household, and farmer characteristics associated with changes in management practices and technology adoption among dairy smallholders. *Trop. Anim. Health Prod.* 47, 311–316. <https://doi.org/10.1007/s11250-014-0720-4>
32. Martínez-González, E.G., Muñoz-Rodríguez, M., García-Muñiz, J.G., Santoyo-Cortés, V.H., Altamirano-Cárdenas, J.R., Romero-Márquez, C., 2011. El fomento de la ovinocultura familiar en México mediante subsidios en activos: lecciones aprendidas. *Agron. Mesoam.* 22, 367–377.
33. Martínez-Peña, M., Villagómez-Cortés, J.A., Mora-Brito, Á.H., 2018. Rentabilidad del sistema de producción ovina en el Bajo Mixe, Oaxaca, México. *Agrociencia Méx* 52, 107–122.
34. Miller, Z.J., Menalled, F.D., Sainju, U.M., Lenssen, A.W., Hatfield, P.G., 2015. Integrating sheep grazing into cereal-based crop rotations: Spring wheat yields and weed communities. *Agron. J.* 107, 104–112. <https://doi.org/10.2134/agronj14.0086>
35. Monke, E. and Pearson, S., 1989. The policy analysis matrix for agricultural development. Cornell University Press, Ithaca and London
36. Morales, M.M., Martínez, D.J.P., Torres, H.G., Pacheco, V.J.E., 2004. Evaluación del potencial para la producción ovina con el enfoque de agroecosistemas en un ejido de Veracruz, México. *Téc Pecu Méx* 42, 347–359.
37. Morantes, M., Dios-Palomares, R., Peña, M.E., Rivas, J., Perea, J., García-Martínez, A., 2017. Management and productivity of dairy sheep production systems in Castilla-La Mancha, Spain. *Small Rumin. Res.* 149, 62–72. <https://doi.org/10.1016/j.smallrumres.2017.01.005>
38. Ndemewah, S.R., Menges, K. and Hiebl, M.R.W. (2019), "Management accounting research on farms: what is known and what needs knowing?", *J Accounting & Organ. Change* 15, 58–86. <https://doi.org/10.1108/JAOC-05-2018-0044>
39. Nuncio-Ochoa, G., Nahed, T.J., Díaz, H.B., Escobedo, A.F., Salvatierra, I.E.B., 2004. Caracterización de los sistemas de producción ovina en el estado de Tabasco. *Agrociencia Méx* 35, 469–477
40. Olaizola, A.M., Chertouh, T., Manrique, E., 2008. Adoption of a new feeding technology in Mediterranean sheep farming systems: Implications and economic evaluation. *Small Rumin. Res.* 79, 137–145. <https://doi.org/10.1016/j.smallrumres.2008.07.022>
41. Partida de la Peña, J.A., Braña, V.D., Jiménez, S.H., Rios, R.F.G., Buendía, R.G., 2013. Producción de carne ovina, Inifap. Available from: https://www.academia.edu/31698469/Producci%C3%B3n_de_Carne_Ovina (accessed 16 August 2020)
42. Posadas-Domínguez, R.R., Del Razo-Rodríguez, O.E., Almaraz-Buendía, I., Pelaez-Acero, A., Espinosa-Muñoz, V., Rebollar-Rebollar, S., Salinas-Martínez, J.A., 2018. Evaluation of comparative advantages in the profitability and competitiveness of the small-scale dairy system of Tulancingo Valley, Mexico. *Trop. Anim. Health Prod.* 50, 947–956. <https://doi.org/10.1007/s11250-018-1516-8>
43. Pulina, G., Milán, M.J., Lavín, M.P., Theodoridis, A., Morin, E., Capote, J., Thomas, D.L., Francesconi, A.H.D., Caja, G., 2018. Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *J. Dairy Sci.* 101, 6715–6729. <https://doi.org/10.3168/jds.2017-14015>
44. Ramirez-Tello, J.A., Torres-Hernández, G., De La Cruz-Colín, L., Ochoa-Cordero, M.A., Suárez-Espinosa, J., 2013. Evaluación de factores ambientales que influyen en características de crecimiento del nacimiento al destete de corderos Hampshire. *Rev. Mex. Ciencias Pecu.* 4, 117–125
45. Rebollar-Rebollar, A., Hernández-Martínez, J., Rebollar-Rebollar, S., Guzmán-Soria, E., García-Martínez, A., González-Razo, F.J., 2011. Competitividad y rentabilidad de bovinos en corral en el sur del Estado de México. *Trop. Subtrop. Agroecosystems* 14, 691–698.
46. Ripoll-Bosch, R., Joy, M., Bernués, A., 2014. Role of self-sufficiency, productivity and diversification on the economic sustainability of farming systems with autochthonous sheep breeds in less favoured areas in Southern Europe. *Animal* 8, 1229–1237. <https://doi.org/10.1017/S1751731113000529>
47. Rivas, J., Manuel Perea, J., De-Pablos-Heredero, C., Morantes, M., Angon, E., Barba, C., García, A., 2019. Role of technological innovation in livestock breeding programmes: a case of cereal-sheep system. *Ital. J. Anim. Sci.* 18, 1049–1057. <https://doi.org/10.1080/1828051X.2019.1609381>

48. Riveiro, J.A., Mantecón, A.R., Álvarez, C.J., Lavín, P., 2013. A typological characterization of dairy Assaf breed sheep farms at NW of Spain based on structural factor. *Agric. Syst.* 120, 27–37. <https://doi.org/10.1016/j.agsy.2013.05.004>
49. Rodríguez-Licea, G., García-Salazar, J.A., Hernández-Martínez, J., 2016. Identificación de conglomerados para impulsar las cadenas productivas de carne en México. *Agron. Mesoam* 27, 353–365.
50. Salamanca, M.I., Gómez, U.N., Soares, F.M.C., Bezerra, S.J.R., 2018. Characterization of sheep breeders and their productive systems in southern coast of Peru. *An. científicos* 79, 182–193.
51. Salcedo, V.S., 2007. Competitividad de la Agricultura en América Latina y el Caribe. Available from: <http://www.fao.org/family-farming/detail/es/c/292331/> (accessed 23 January 2020)
52. Salinas-Martínez, J.A., Posadas-Domínguez, R.R., Morales-Díaz, L.D., Rebollar-Rebollar, S., Rojo-Rubio, R., 2020. Cost analysis and economic optimization of small-scale dairy production systems in Mexico. *Livest. Sci.* 237, 104028. <https://doi.org/10.1016/j.livsci.2020.104028>
53. SAGARPA. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. 2018. Creció 70 por ciento la producción en el sector ovino nacional con alta calidad genética: SAGARPA. Available from: <https://www.inforural.com.mx/crecio-70-por-ciento-la-produccion-en-el-sector-ovino-nacional-con-alta-calidad-genetica-sagarpa/> (accessed 15 September 2019)
54. SIAP. Servicio de Información Agroalimentaria y Pesquera. 2019. Anuario Estadístico de la Producción Ganadera. Available from: <https://www.gob.mx/siap/acciones-y-programas/produccion-pecuaria> (accessed 15 January 2019)
55. Theodoridis, A., Ragkos, A., Roustemis, D., Galanopoulos, K., Abas, Z., Sinapis, E., 2012. Assessing technical efficiency of Chios sheep farms with data envelopment analysis. *Small Rumin. Res.* 107, 85–91. <https://doi.org/10.1016/j.smallrumres.2012.05.011>
56. Tindano, K., Moula, N., Traore, A., Leroy, P., Antoine-Moussiaux, N., 2015. Characteristics and typology of sheep herding systems in the suburban area of Ouagadougou (Burkina Faso). *Arch. Anim. Breed.* 58, 415–423. <https://doi.org/10.5194/aab-58-415-2015>
57. Toro-Mujica, P., García, A., Gómez-Castro, A.G., Acero, R., Perea, J., Rodríguez-Estévez, V., Aguilar, C., Vera, R., 2011. Technical efficiency and viability of organic dairy sheep farming systems in a traditional area for sheep production in Spain. *Small Rumin. Res.* 100, 89–95. <https://doi.org/10.1016/j.smallrumres.2011.06.008>
58. UN. United Nations. 2019. World Population Prospects 2019, Department of Economic and Social Affairs. Available from: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf (accessed 20 October 2019)
59. Vélez, A., Espinosa, J.A., De la Cruz, L., Rangel, J., Espinoza, I., Barba, C., 2016. Caracterización de la producción de ovino de carne del estado de Hidalgo, Mexico. *Arch. Zootec.* 65, 425–428. <https://doi.org/10.21071/az.v65i251.708>
60. Vértiz, P., 2016. El rol de la pluriactividad en la persistencia de la producción familiar láctea en la cuenca de Abasto Sur de Buenos Aires. *Trab y Soc.* 475–499.
61. Voors, M.J., D’Haese, M., 2010. Smallholder dairy sheep production and market channel development: An institutional perspective of rural Former Yugoslav Republic of Macedonia. *J. Dairy Sci.* 93, 3869–3879. <https://doi.org/10.3168/jds.2009-2685>
62. Wilkinson, J.M., 2011. Re-defining efficiency of feed use by livestock. *Animal* 5, 1014–1022. DOI: 10.1017/S175173111100005X
63. Zygogiannis, D., 2006. Sheep production in the world and in Greece. *Small Rumin. Res.* 62:143–147. <https://doi.org/10.1016/j.smallrumres.2005.07.043>

Tables

Table 1 Sample size of sheep farms

Stratum	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
	N_1	n_1	N_2	n_2	N_3	n_3	N_4	n_4
Sample size	400	26	350	23	130	9	120	8

Where: N_i , total number of farms in stratum (i); n_i , farms in sample by stratum (i).

Due to technical limitations, table 2 is only available as a download in the Supplemental Files section.

Table 3
Characteristics of the farms by stratum

Strata					
	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Significance test ¹
Characteristics	(n = 26)	(n = 23)	(n = 9)	(n = 8)	
Male owners of the farms (%)	94.40 ns	88.89 ns	85.71 ns	80.00 ns	0.79
Age (years)	53.11 ns (16.46)	59.33 ns (13.16)	63.00 ns (13.40)	65.80 ns (13.10)	0.23
Schooling (years)	6.00 ns	3.50 ns	5.50 ns	6.00 ns	0.54
Years in the activity	6.00 ns	5.50 ns	6.00 ns	10.00 ns	0.25
Farm size (number of fattened sheep)	16.50 a	52.50 b	93.00 bc	130.00 bcd	0.00
Hampshire breed (% yes)	50.00 ns	66.67 ns	57.14 ns	80.00 ns	0.59
Backyard production system (% yes)	83.33 ns	88.89 ns	71.43 ns	45.00 ns	0.07
Mean values with standard deviation are presented in brackets for continuous qualitative variables with normal distribution; for continuous qualitative variables with non-normal distribution the median value is presented.					
¹ Significance level at a p-value = 0.05.					
Values in the same row with a different letter indicate statistically significant differences (p < 0.05); ns = no statistically significant differences.					

Table 4
Main technical and economic indicators by stratum

Strata					
	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Significance test ¹
Characteristics	(n = 26)	(n = 23)	(n = 9)	(n = 8)	
Sheep sale on the market for <i>barbacoa</i> meat (%) sale of live animals	77.80 ns	94.40 ns	100.00 ns	100.00 ns	0.20
Production system based on grazing (% yes)	88.90 ns	94.40 ns	85.70 ns	80.00 ns	0.79
The farm is the only income source (% yes)	55.60 ns	59.32 ns	70.72 ns	80.67 ns	0.38
In the dry season, forage or compound concentrate supplements are offered (% yes)	66.70 ns	83.12 ns	85.70 ns	87.34 ns	0.06
Hires workforce (% no)	90.00 ns	94.00 ns	71.400 ns	70.12 ns	0.44
Does the wife partake of the farm activities? (% yes)	38.90 ns	35.80 ns	70.00 ns	61.00 ns	0.20
¹ Significance level at a p-value of 0.05; ns = no significant differences.					

Table 5
Production cost by stratum (USD per head)

Strata								
	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
Concept	(USD\$)	(%)	(USD\$)	(%)	(USD\$)	(%)	(USD\$)	(%)
Marketable supplies	67.65	86.4	68.55	90.32	64.82	87.73	62.77	88.36
Feed								
Grazing	15.27	19.5	16.39	21.59	12.01	16.25	9.31	13.1
Purchased feed	1.89	2.41	0.97	1.28	2.00	2.71	2.33	3.28
Sheep acquisition (cost/head)	49.20	62.85	49.20	64.82	47.87	64.79	47.87	67.39
Health care (medications)	1.29	1.64	1.99	2.62	2.94	3.97	3.26	4.59
Production factors	10.64	13.6	7.35	9.68	9.06	12.27	8.27	11.64
Land	0.23	0.29	0.07	0.1	0.04	0.06	0.03	0.04
Hired workforce	3.82	4.88	0.73	0.96	2.94	3.99	1.72	2.42
Services (water and electricity bills)	5.97	7.63	6.23	8.21	5.85	7.92	6.32	8.89
Depreciation of implements	0.42	0.54	0.13	0.18	0.08	0.1	0.06	0.08
Infrastructure depreciation	0.20	0.26	0.19	0.25	0.15	0.21	0.15	0.21

Table 6
Private profitability and competitiveness indicators

	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
Entry	With grazing	Without grazing	With grazing	Without grazing	With grazing	Without grazing	With grazing	Without grazing
Private profitability ratio (% / invested USD\$)	0.53	0.20	0.58	0.23	0.62	0.25	0.72	0.32
Private cost ratio	0.20	0.35	0.14	0.25	0.17	0.27	0.14	0.22

Figures

Figure 1

Analysis of net costs and benefits with and without grazing

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table2.jpg](#)