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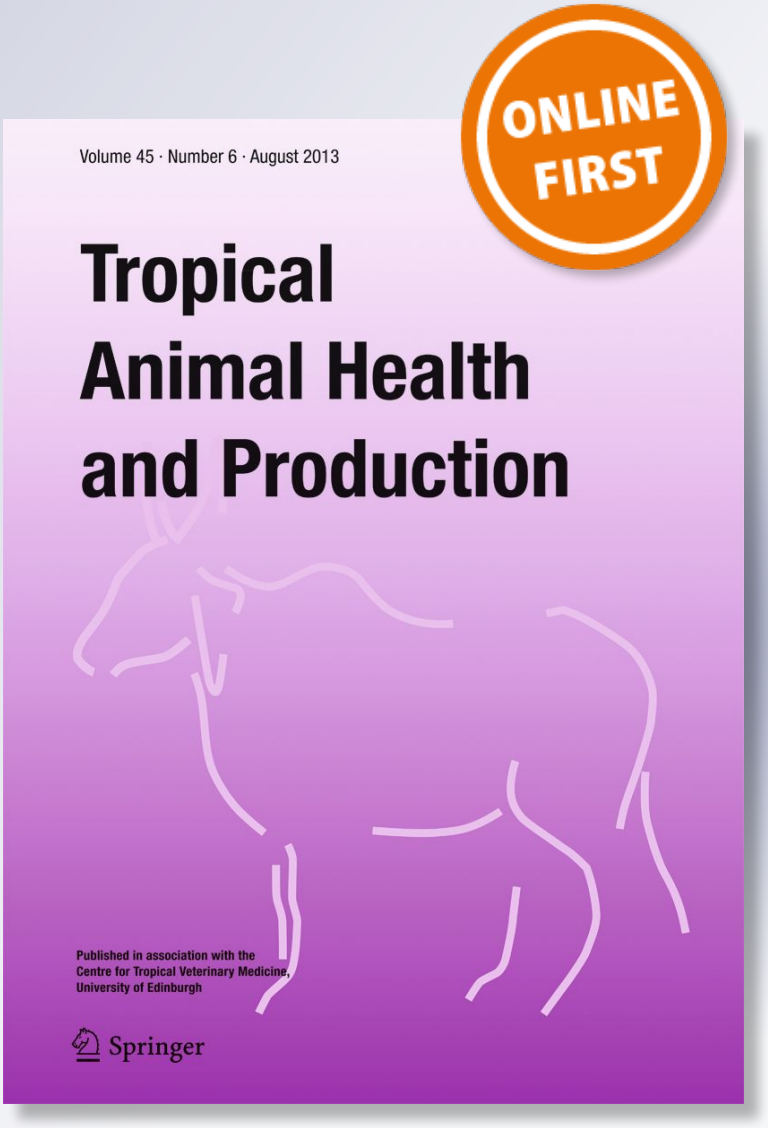

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REGULAR ARTICLES

Altitude effects on technology and productivity of small bovine farms (milk meat) in Veracruz (Gulf of Mexico)

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Abstract The dual-purpose bovine system represents 98.4% of the bovine livestock of Veracruz, the main cattle-producing state of Mexico. This system supplies calves to meat companies, a sector in which Veracruz has been the national leader in the last decade. The objective of the present study was to analyze the effect of the altitudinal zonation of farms on livestock technology and productivity in a microbasin of the Gulf of Mexico where small farms predominate. Structured interviews were applied to producers located in three altitudinal zones (at average altitudes of 50, 140, and 450 m, respectively, for lower, middle, and upper zones). Sample size was 135 farms having similar land surface (within a range of 15–22 ha). The results indicated multiple differences among farms located in the three zones. Farms in the middle and lower zones presented higher productive indicators than those in the upper zone. Differences in herd structure and management resulted in important differences in productivity, income, and profits in milk and calf production. We concluded from this study that altitudinal zonation in Veracruz had a clear effect on the differentiation of small farms, which are representative of dual-purpose cattle. The upper zone performs cattle activity under conditions with greater disadvantages in the analyzed region.

Keywords Dual-purpose cattle production · Small livestock farms · Rural development · Tropical grasses · Poverty · Climate change · Sustainability

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Introduction

In the Gulf of Mexico, the dual-purpose system (milk and meat) prevails in farms that are characterized by low capital investment, whose land has few alternatives of use and sales for local markets. This system has evolved very little in technology, records of activities in the farms, and genetic improvement of herds. The importance of the dual-purpose system is due to the volume of milk and meat production, on the one hand, and on the other, to income deriving from the livestock activity, which aids in the reproduction and economic stability of small farms.

The majority (> 98%) of livestock in Veracruz corresponds to the dual-purpose cattle system (CTEE 2014). The bovine population in Veracruz state was 4.8 million heads, 54% corresponding to bellies (SINIIGA 2016).

Livestock farms in Veracruz consisted of small surfaces under extensive livestock systems occupying a wide variety of ecosystems. The animals belong to indefinite crosses between European breeds and Zebu-type cattle. The feeding of livestock depends nearly exclusively on grassland, which continues to be largely represented by native species

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of low forage value. The altitudinal zonation in Mexico is associated with an intricate mountain system and inequalities within communal property inherited from colonial legacy; in high-altitude regions, the areas susceptible to grazing and agricultural activity are reduced for feed production in comparison to lowlands (Alix-García 2011). Little has been investigated on how altitudinal zonation in watershed microbasins affects livestock activity in a mountainous country such as Mexico and in particular in a region with high cattle activity as occurs in Veracruz state.

The objective of the present investigation was to compare the effect of altitude on farm and livestock resources, technology, and the economic performance of dual-purpose cattle farms in a region of the state of Veracruz. Farms were sampled on a gradient that covered from the lowlands to elevated area formed by hills.

Materials and methods

Geographic location and physical data

The study area is located in the south of the state of Veracruz in the Gulf of Mexico. It belongs to a region whose native tropical vegetation has been nearly entirely replaced by extensive livestock activity in the second half of the twentieth century, and by sugarcane and other crops (González-Abraham et al. 2015). Land distribution in the early part of the twentieth century strengthened common ownership in favor of families with small land surfaces (1–20 ha; Alix-García 2011). Within the context of the country of Mexico, the study area is located in an ecoregion with a high and very high human footprint due to the presence of agriculture, oil exploitation, dam construction, electricity generation, and a network of roads that connects the south and SE of Mexico with the political center (Mexico City) and the north of the country (González-Abraham et al. 2015).

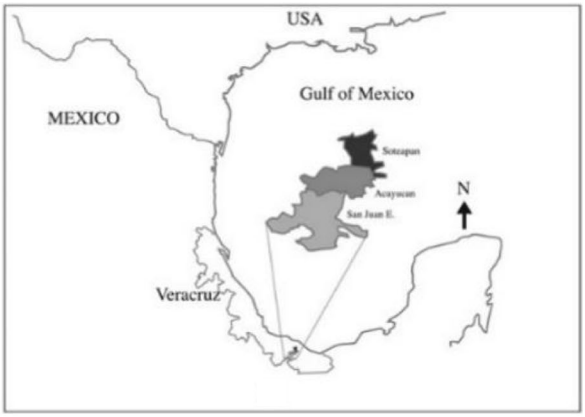
The Michapan microbasin is located here, and it begins at 18°20′2.84″N–94°56′44.05″W and converges at 17°58′43.11″N–95°9′57.62″W. It is an affluent of the San Juan River that empties into the Papaloapan River basin. The Michapan River originates in the municipality of San Pedro Soteapan (upper zone) and, along its route, it crosses Acayucan (middle zone) and ends up in San Juan Evangelista (lower zone) in the south of the state of Veracruz (Fig. 1) (CNA 2012). The current investigation focused on farms located in the three zones of the Michapan Microbasin (Table 1). These altitudinal zones are representative of the relief of the state of Veracruz; according to INEGI (2016): 36% of the State is plains, 38% hills, and 20%, mountains.

Sampled and analyzed farms

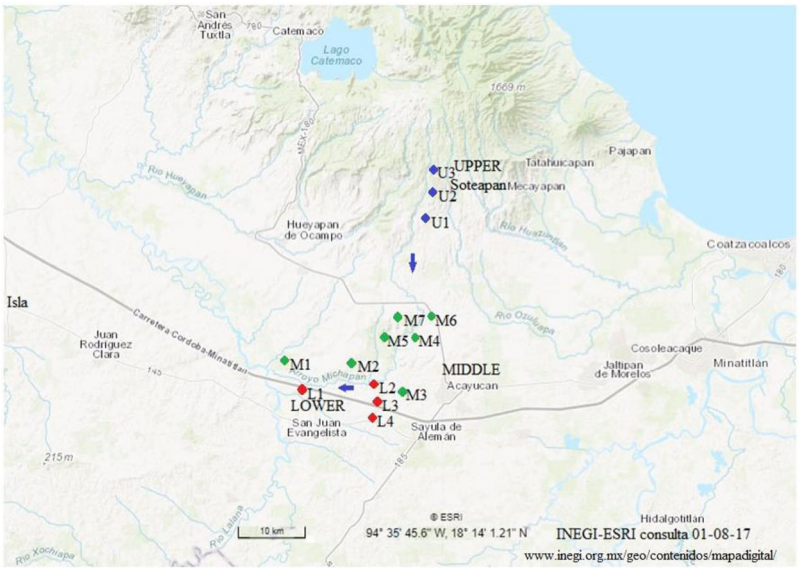
The livestock farms recorded in the National Cattle Identification System (SINIIGA) registered in 2013, located in the Michapan micro-watershed, belong to 15 communities dedicated to livestock, with 3 communities in the municipality of San Pedro Soteapan (upper zone), 8 in Acayucan (middle zone), and 4 in San Juan Evangelista (lower zone). Total farms comprised 1282: 436 of Soteapan; 596 of Acayucan, and 250 of San Juan Evangelista. Farm stratification was performed in farms with dual-purpose livestock; first, average farm surface-by-municipality was determined, and only farms whose surface area (ha) was less than 1 ha of the standard deviation (SD) of the municipality's average farm surface, with at least one belly per hectare were included in the study. In this manner, farms where livestock was not the main activity were excluded. The population resulting from the stratification included 206 livestock farms, with '*ejidal*' (common land) land tenure as a whole. To determine the farm sample size (n = 135), the equation proposed by Scheaffer et al. (1987) was used, $n = \frac{\left(\Sigma_i^L = 1 Nisi\right)^2}{N^2 D + \Sigma_i^L = 1 Nisi}$ where n = sample size, L = number of strata, Ni = number of sampled farms in stratum i, N = total sampled farms in the population, si = variance of the i-th stratum, and D = limit of estimation error. Assignment of the sample to each stratum $ni = \left[\frac{Nisi}{\Sigma_i^L = 1 Nisi}\right]$ where ni = size of the sample in the stratum i, and n, L, Ni, N, si remain as previously defined. Sampling process yielded 15, 93, and 27 farms for upper, middle, and lower areas, respectively, which indicates that in the Michapan Basin, the middle zone (Acayucan) has a larger number of farms dedicated to dual-purpose cattle production than the upper zone (Soteapan) and the lower zone (San Juan Evangelista). Once the producers agreed to participate in the investigation, information was collected during the period from March to November 2014; during June 2015 and June 2016, a second visit was made to some farms in order to corroborate information. The survey was conducted through a structured farmer interview. Field observations served to verify the information collected on each surveyed farm.

Highly discriminating variables were selected to characterize farms in terms of land and animal units, herd structure, productive and reproductive indicators, and profitability. The following information was included in the farm dimension (category 1): total area (ha), herd size in animal units (AU, 450 kg of live weight), and milk production. Regarding herd structure (category 2), the variables were head as unit, nursing cows, dry cows, heifers, female and male calves, and stallions. Reproduction and production indicators included calving (%), mortality (%), and milk production (L day^{-1} farm^{-1}). In grazing and management (category 3), variables comprising the area with improved pasture species (%), farms managed with rotational grazing (%), and animal load (AU ha^{-1}) were considered. For farm profitability (category 4), the variables collected were

(a)



(b)



National and regional roads appear in the map and blue arrows indicate the direction of Michapan river flow.

Zones

Upper
Middle
Lower

Community	Altitude (m)
U1 Morelos	386
U2 B. Vista	518
U3 B. Juarez	548
M1 Cascajal	95
M2 Aguapinole	95
M3 C. y Piña,	100
M4 M. Paso Real	100
M5 E. Malota	117
M6 Ixtagapan	133
M7 Quiamoloapan	178
L1 La Lima	28
L2 M. de Osorio	41
L3 La Cerquilla	60
L4 V. Hermosa	75

Fig. 1 Geographic information. **a** Map of three municipalities in Veracruz State (Mexico). **b** Satellite image (INEGI-ESRI©) with the communities where farm survey was carried out

milk income per year, calf sales per year, fixed costs per year, variable costs per year, and profitability per hectare.

Statistical analysis

The database was designed with the field information. The variables were classified and debugged. Later, the matrix was generated with characteristics for its processing in the IBM SPSS Statistics (version 22) statistical software program. A one-way analysis of variance was carried out with the altitude variable as the independent variable, with three levels (lower, middle, and upper) and, as dependent variables, those listed previously for the four categories. When significant differences resulted due to the altitudinal position of the farms, comparisons were made between the average values of the variables analyzed by means of the Tukey test (IBM 2013). Mean values and SD were tabulated for the different analyzed variables.

Results and discussion

Typical farm in the Michapan Basin

Regarding cattle in the region consisting of Swiss-Zebu crosses, the main source of food is based on grazing, and the

Table 1 Climate and socio-economic conditions at the three altitude zones at Michapan micro-watershed (Veracruz State)

Indices	Altitude zones		
	Upper	Middle	Lower
Climate and its municipal proportion (%)	Af (36) Am (28) Aw (21) Aw_2 (15)	Aw (100)	Aw_2 (91) Aw_1 (8) Am (1)
Annual temperature range (°C)	20–26	24–28	24–28
Annual rain (mm)	1900–4600	1400–1600	1400–1600
Altitude (m)[a]	548–386	95–178	28–75
Soil agriculture use (%)	37	34	7
Soil pasture use (%)	37	58	84
Mechanizable surface land (%)	16	86	78
Farm surface (ha)	16.5	22.3	14.9
Municipality	Soteapan	Acayucan	San Juan E.
Population in 2015	35,155	87,267	33,929
EAP at primary sector (%)	73.3	18.5	54.8
Marginalization index	Very high	Intermediate	High
Poverty (%)	92.8	71.3	78.5
Extreme poverty (%)	61.5	21	30.8
Indigenous population (%)	84.3[b]	5	1
Illiteracy (%)	32.5	9.9	14.4
Human development index	Intermediate	Intermediate	Intermediate
Index of social lag	High	Low	Intermediate

Main source: INEGI (2009)

Af humid warm with rains all year, *Am* humid warm with summer rains, *Aw* sub-humid warm with summer rains (0, 1, and 2 subscript denotes an increasing gradient of humidity) (García 2004), *EAP* economically active population

[a] Altitude ranges correspond to the communities included in the sampled farms

[b] Zoque-Popoluca; indigenous language dominant at Soteapan

breeding system is by natural mating. The period of milking lasts approximately 240 days, and the milk and calf trade is at the local level. Calves are sold at an approximate weight of 150–180 kg. The main diseases that affect the farms are pasteurellosis pneumonia, clostridiosis, bovine paralytic rabies, and parasitic diseases, both internal and external. The farms' main facilities are corrals and galleys for milking, with low technology. Farms do not have productive and economic records. The main workforce is supplied by the owner-couple with the support of their children. Income from the sale of milk is the main operational resource of the farm and the family.

Farm surface, animal unit, and milk production at the three altitudinal zones

The farm in the middle zone (Acayucan) had an average area of farms larger than 5 and 7 ha in relation to the farm in the low (San Juan Evangelista) and the upper zones (Soteapan), respectively. These differences were significant (Table 2). In relation to the number of animal units in each farm, the results indicated differences for the basin's three zones ordered as follows: middle > lower > higher (Table 2). The number of animal units in the farms in the middle zone was twice as high as in farms located in the upper zone, which indicates a strong difference in the intensification level of the dual-purpose system for farms with small areas of land in the region. In relation to daily milk production, the middle and lower basins were similar, having the highest values and presenting a significant difference ($p < 0.01$) compared with those from the upper zone (Table 2). Daily milk production by farm was three times higher in the middle than in the upper zone. These results indicate that altitudinal zonation exerts an influence on herd dimension and milk production.

Herd structure and production indicators

The livestock inventory is very dynamic throughout the year due to the physiological status of adult (calving and dry) cows, the development of replacement females, calving, mortality, calf sales, and adult livestock waste, either on a scheduled basis or to cover the eventualities of the farm (Table 3). Comparisons of herd production indicators revealed differences ($p < 0.01$) among farms located at different altitudinal

Table 2 Farm surface (ha), animal units, and farm daily milk production (liters by day by farm) at the three zones of Michapan microbasin; means ± standard deviation

Variables	Mean (n = 135)	Upper (n = 15)	Middle (n = 93)	Lower (n = 27)
Farm surface (ha)	20.2 ± 6.96	16.5 ± 1.36b	22.3 ± 6.69a	14.9 ± 6.08b
Animal units per farm	36.4 ± 12.45	21.9 ± 6.31c	40.0 ± 11.30a	32.1 ± 11.73b
Milk production (L day^{-1} farm^{-1})	54.4 ± 17.80	21.8 ± 4.58b	60.4 ± 13.60a	52.0 ± 14.88a

Means with different letter (horizontally) correspond to different mean groups ($p < 0.05$)

zones. The number of lactating cows was nearly twice as high in farms of the middle basin compared to those of the upper basin (Table 3). In relation to the number of dry cows, the upper and lower basins presented values without statistical differences between them (Table 3), but different from those of the middle zone, which had the highest value. The number of heifers was equal in the three zones of the basin, with the greatest tendency in the middle zone (Table 3). The number of female calves presented highly significant differences ($p < 0.01$) among the three altitudinal zones; the number of female calves in the middle zone was nearly three times higher than in the upper zone ($p < 0.01$) (Table 3). When comparing male calves of the middle and lower zones, these were not different from each other and higher than the average of the upper zone (Table 3). The mean number of stallions in the middle zone was higher than in the upper zone (Table 3). Average calving on farms of the middle and lower zones was similar but different from those observed in the farms of the upper zone. Mortality values were lower in the farms of the middle and lower areas and higher in those of the upper zone (Table 3). Regarding lactation (L cow^{-1} year^{-1}), the highest value corresponded to the farms of the lower zone, followed by those of the middle and upper zones (Table 3). Overall, data of the analyzed indicators revealed a better performance for the farms of the middle zone (Acayucan), followed by those of the lower zone (San Juan Evangelista), although highest intensification of animal load corresponded to the lower zone. A similar performance trend was observed between farms in the middle and lower areas, and these were different in relation to farms located in the upper zone (Soteapan) that, in the majority of positive production indicators (nursing cows, heifers, female and male calves, lactation), demonstrated minimal average values, while the mortality indicator had the highest value (Table 3).

Grazing and livestock management

In addition to farm area and herd size, management of the production system and feeding strategies are crucial, because they exert a strong influence on the income obtained by the farms (Espinoza-Ortega et al. 2005). In relation to the surface occupied by improved pastures of the genus *Brachiaria*, *Cynodon*, and *Panicum*, the middle and lower zones presented similar values (average of 80% of the surface) and different values with respect to those of the upper zone (40% of the surface) ($p < 0.01$). Additionally, surface-under-grazing reached the maximal value (84% of the farms surface) in the lower zone, while the minimal surface was observed in the upper zone. This result indicates that the use of pastures in farms in the upper zone is less intensive, which is consistent with the smaller size-of-herd in this zone (Table 1). Additionally, grazing type differs among the basin's altitudinal

Table 3 Herd structure and production indicators for the three altitude zones at Michapan microbasin; mean ± standard deviation

Farm indices	mean (n = 135)	Upper (n = 15)	Middle (n = 93)	Lower (n = 27)
Nursing cows (number)	20.3 ± 6.36	11.2 ± 2.81c	22.4 ± 5.45a	18.1 ± 5.46b
Dry cows (number)	10.1 ± 4.78	6.5 ± 3.72b	11.3 ± 4.78a	8.0 ± 3.57b
Heifers (number)	8.7 ± 6.23	5.9 ± 2.46a	9.5 ± 6.67a	7.3 ± 5.55a
Female calves (number)	9.8 ± 4.11	4.4 ± 1.35c	11.2 ± 3.79a	7.9 ± 2.75b
Male calves (number)	9.5 ± 3.65	5.6 ± 1.68b	10.1 ± 3.71a	9.3 ± 2.89a
Bull stallion (number)	1.4 ± 0.54	1.0 ± 0.00c	1.4 ± 0.56a	1.3 ± 0.56ab
Calving (%)	53.3 ± 6.06	48.9 ± 6.32b	53.3 ± 5.68a	55.7 ± 6.04a
Mortality (%)	5.5 ± 1.17	7.9 ± 0.92a	5.5 ± 0.88b	5.4 ± 0.93b
Lactation (L cow^{-1} year^{-1})	971.9 ± 115.21	721.6 ± 80.35c	988.4 ± 72.60b	1054.2 ± 46.08a

Means with different letter (horizontally) correspond to different mean groups ($p < 0.05$). Calving formulae = (number of calves) (productive cows + dry cows + heifers)$^{-1}$ (year)$^{-1}$; Mortality formulae = (adult and calves deaths) (total heard)$^{-1}$ (year)$^{-1}$

Table 4 Surface with improved pastures, rotational grazing, and animal unit intensity for the farms (LU) at three altitude zones; mean ± standard deviation

Variables	General mean (n = 135)	Upper (n = 15)	Middle (n = 93)	Lower (n = 27)
Improved pastures surface (%)	77.9 ± 19.9	38.0 ± 23.9b	84.7 ± 10.1a	76.6 ± 17.3a
Farms with rotational grazing (%)	58.5	40a	57a	74a
Animal unit intensity (AU ha^{-1})	1.8 ± 0.47	1.3 ± 0.40b	1.8 ± 0.41a	2.2 ± 0.44a

Means with different letter (horizontally) correspond to different mean groups ($p < 0.05$)

zones, since only 40% of farms in the upper zone employ rotational grazing, while in the middle and lower zones, rotational grazing is carried out on 57 and 74% of the farms, respectively (Table 4). Animal load presented highly significant differences among the three zones ($p < 0.01$). The highest value was observed in the lower-zone farms, followed by those of the middle and upper zones (Table 4). Species of the *Brachiaria* genus are those most frequently utilized in the livestock sector of dual-purpose cattle in tropical areas (Olivera et al. 2006). Rotational grazing of improved forages not only increases animal productivity but also reduces soil erosion. The main effect of improved forage-species use is reflected in the higher animal load pasturing and, to a lesser degree, in daily increases in milk-per-cow production (Argel 2006).

Profitability of farms

Farm average income from the sale of milk was nearly three times higher in the middle and lower areas compared to the income obtained by farms in the upper area (Table 5); differences were statistically significant ($p < 0.01$). Regarding income from the calves' sales, farms in the middle and lower areas reflected nearly double the sales as those of upper-area farms (Table 5).

Fixed costs were higher on farms of the basin's middle and lower zones than those of the upper zone ($p < 0.01$) (Table 5). Labor was classified as a fixed cost because it is the responsibility of the farm and does not depend on production volumes (Jiménez-Jiménez et al. 2008). In the upper basin, labor represented 82% of the fixed cost, while in the middle and lower basins, this was around 65%. These high proportions are due to the self-employment of the head of household and to the children supporting the productive activities. Variable costs were different in the three zones and constituted 9, 30, and 22% of total cost of farms of the upper, middle, and lower areas, respectively. The higher proportion of variable costs invested in the middle and lower areas mainly corresponds to inputs for the care and management of livestock and pastures, which is reflected in the higher productivity of farms in these zones of the watershed basin.

Regarding the utility of the farms, significant differences ($p < 0.01$) were observed when the upper zone was compared to the middle and lower zones. Utility per hectare presented differences among the three zones of the basin, with the highest value in lower-zone farms, followed by farms in the middle and upper zones. This higher farm utility in lower and middle zones allows greater reinvestment in the farms, while in the upper zone and with lower farm incomes (Table 5), the money is allotted to cover basic family expenses. The low utility of the upper-zone farms is consistent with their animal unit, pastured area, management type, and herd-performance indicators. Social and financial capital comprises the most influential factors in the adoption of technologies for small producers who are in charge of dual-purpose bovine system units (Forero-Camacho et al. 2013).

Previous studies in Veracruz (Vilaboa-Arroniz et al. 2009; Juárez-Barrientos et al. 2015) characterized the socioeconomic and technological components of three types of livestock farms (traditional, transitional, and business). The results

Table 5 Comparison of income, cost, and profit (thousands Mexican pesos) for the farms in the three altitude zones of Michapan basin

Variables	Mean values (n = 135)	Upper (n = 15)	Middle (n = 93)	Lower (n = 27)
Milk income	98.9 ± 33.29	35.8 ± 7.16b	110.2 ± 24.81a	95.0 ± 27.16a
Cattle income	71.5 ± 31.04	36.0 ± 12.47b	77.3 ± 31.59a	71.2 ± 22.43a
Fixed cost	65.4 ± 9.91	44.5 ± 0.66b	68.1 ± 6.69a	67.5 ± 8.02a
Variable cost	17.6 ± 9.34	3.9 ± 0.86c	20.5 ± 8.23a	15.3 ± 8.13b
Profit	87.4 ± 44.38	23.4 ± 17.84b	98.8 ± 40.91a	83.3 ± 34.78a
Profit/ha	4.4 ± 2.06	1.4 ± 1.11c	4.5 ± 1.83a	5.7 ± 1.5b

Mean ± standard deviation. Mean values with different letter correspond to different mean groups ($p < 0.05$)

Table 6 Qualitative data related with roads, cattle and milk trade, and actions to surpass the farm constraints at each altitudinal zone

Qualitative data	Upper zone *Soteapan*	Middle zone *Acayucan*	Lower zone *San Juan E.*
Condition of the main roads connecting human settlements	Acceptable condition	Acceptable condition	
Condition of farm roads to access to grazing lands	Bad condition	Acceptable condition	
Accessibility of regional cattle buyers	Low (1–2 buyers)	High (> 10 buyers)	
Accessibility to regional certified traces	Null	At Acayucan	At Acayucan and Isla
Accessibility of regional buyers of milk	Low (1 buyer)	Middle (> 5 buyers) Artisanal cheese	
Farm constraints to be surpassed in order to increase livestock productivity and profitability	(1) Technical assistance in each aspect of technology. (2) Encourage cooperation among producers. (3) Improved grasslands and (4) improving animal nutrition and health. (5) Improve products trading.	(1) Animal breeding, improvements in animal nutrition and health. (2) Management and business approach. (3) Formalize organizations to unite efforts and resources. (4) Give added value to production. (5) Access to agricultural loans.	

demonstrated that > 90% of farms were classified as traditional due to their low productivity, technological level, and income. The main differences among farms were technological components used, farm size, animal units, animal load, and sale of animals per year. For the southern region of Veracruz, Díaz-Rivera et al. (2011) and Oros-Noyola et al. (2011) found that approximately 80% of units have low technological levels. Our results confirm the low productivity, low technological level, and low income of the units that predominate in Veracruz. One aspect to emphasize is that under a segmented altitudinal approach, we have the capacity to locate, with greater precision, heterogeneities in the structure and technology of the livestock farms with comparable owned farmland. The work of governmental programs can be facilitated to orient their public policies according to the dominant characteristics of the farms in each altitude zonation.

Perspectives of dual-purpose small farms in Veracruz

Increasing productivity in meat and milk is a goal to be achieved in small farms around the world (Thornton 2010). This aspect addresses the growing need for animal products and, at the same time, improves the well-being of family farmers who raise livestock (Oosting et al. 2014). In the region under study, farms of the three altitudinal zones would benefit from further increases in productivity; however, farms with the greatest technological and productivity deficiencies, located in upper lands, should be a priority for the different actors of rural development in the region.

The upper zone presents rugged hill topography that hinders access to grazing areas, which comprises an obstacle to the commercialization of animals and by-products (Table 6). Cultural barriers linked to the marginalization of Zoque-Popoluca indigenous communities living in the upper zone also negatively affects the negotiation capacity of farm owners.

While in the three areas of the microbasin under study, family-type units predominate, whose objectives integrate a self-employment strategy, the results of the present investigation clearly indicated important differences in the economic performance of milk and cattle production. The results of herd management and of the technological level of the producers denote important differences in productivity, income, and profits. This coincides with what was observed by Orantes-Zebadúa et al. (2014) in the state of Chiapas, Mexico.

Farms in the upper zone are those that should be a priority in rural development programs, so that the adults and young people involved in the succession of property receive the support that allows them to progress in their economic activity and the knowledge of climate change risks (Rojas-Downing et al. 2017). Given the importance of small farms with respect

to feeding the world population, it is indispensable that regions of livestock production in extensive systems, such as that analyzed here, receive greater attention from public policies. (Herrero et al. 2010).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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