



Is the increase of scale in the tropics a pathway to smallholders? Dimension and ecological zone effect on the mixed crop-livestock farms

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Abstract

Mixed crop-livestock farms are widely spread in different tropical regions in the world; they contribute to food security, rural development, sustainability and poverty alleviation. The effect of scale on performance of dual purpose (DP) cattle farms was evaluated in two Mexican ecological zones: dry (DT) and wet tropics (WT). In 2011, a questionnaire of 184 items distributed into technical and social characteristics was applied to a representative sample of 3,285 farms with 50 or less cows (0.97%). The farms were classified into three groups according to their dimension: very small (1-9 cows), small (10-19 cows) and medium (20-50 cows). A general linear model (GLM) with two factors and their interactions was applied. Significant effects in dimension and ecological zone were found as well as seven interactions between both factors ($p < 0.05$). Native pastures were used in all farms for grazing. However, small farms' herds frequently grazed on cultivated pastures and on crop residues ($p < 0.05$). Medium farms showed the highest grazing surface, but in the WT silage and green fodder were used while in the DT dry fodders were used ($p < 0.001$). The interactions between factors showed a bigger specialization in milk production in DT farms, whereas WT farms were more specialized in meat production. The mixed crop-livestock system in tropic region requires an increase in herd size according to farm's own productive structure, which is strongly influenced by the ecological zone. The systems would improve with the active participation of smallholders to identify and achieve best practices, higher technological adoption level and with an effective support from public and private Institutions.

Additional keywords: marginalization; subsistence; dual purpose; tropics; resilience.

Abbreviations used: AU (animal unit); DP (dual purpose); DT (dry tropic); GLM (general linear model); UW (unit of work); WT (wet tropic).

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Introduction

Low input livestock systems supply 19% and 12% of world production of milk and meat, respectively. On one hand, they constitute a key tool for food security because they are readily available, supply the market, facilitate access to food and stabilize production (FAO, 2012; Steinfeld *et al.*, 2006). Livestock is a factor of social cohesion and availability of financial assets. On the other hand, small-scale production enhances

environmental sustainability and contributes to the mitigation of greenhouse effect due to technological development and systems adaptation (Gerber *et al.*, 2013). The use of crop residues and agricultural by-products into the ruminant diet could help to decrease methane production and excretion of nitrogen through the urine, which is considered an important environmental concern (Romero-Huelva *et al.*, 2013).

Van't Hooft & Wollen (2012) and Gerber *et al.* (2013) affirm that the most frequent farming

systems in developing countries are composed by smallholders, which usually live around the poverty line, in marginal areas, with vulnerable agro-ecological conditions and basic infrastructures (Ferguson *et al.*, 2013; Harvey *et al.*, 2014). Smallholders' farms present low levels of technological adoption (Rege *et al.*, 2011; Cortéz-Arriola *et al.*, 2015) and difficult access to external inputs, as well as a vulnerability to natural disasters and other economic and social problems (Oosting *et al.*, 2014).

Dual Purpose (DP) livestock system has been widely described by Espinosa & Wiggins (2003), Bartl *et al.* (2009) and Rojo-Rubio *et al.* (2009). In American tropic regions, it is located from Mexico (Hernández-Morales *et al.*, 2013; Albarran-Portillo *et al.*, 2015; Salas-Reyes *et al.*, 2015) to northern Brazil (García-Martínez *et al.*, 2016), including Venezuela (Urdaneta *et al.*, 2013), Colombia (Cortés-Mora *et al.*, 2014), Ecuador (Torres *et al.*, 2015), Costa Rica and Peru (Bartl *et al.*, 2009; Lentés *et al.*, 2010). DP is a variation of smallholder mixed crop-livestock system with a part of grazing native pasture on communal lands, within a multifunctional livestock that produces both milk and meat (FAO, 2012; Herrero *et al.*, 2013; Oosting *et al.*, 2014). The DP is complex, heterogeneous and influenced by several factors such as dimension, availability of resources, level of technological adoption and agro-climatic conditions (Bernués & Herrero, 2008; Oros *et al.*, 2011). Cuevas-Reyes *et al.* (2013) mention that the dimension is the main factor to determinate the technological level. In Mexico, the DP system is mainly characterized according to technical, geographic, edaphological, social and economic aspects (Díaz-Rivera *et al.*, 2011; Albarran-Portillo *et al.*, 2015; Cortéz-Arriola *et al.*, 2015; García-Martínez *et al.*, 2015). Espinosa & Wiggins (2003) and Hernández *et al.* (2013) indicated that DP farms generally have less than 30 production cows. In addition, specialized knowledge about external and internal effects on productive structure is limited or non existent, particularly regarding dimension and ecological zone. According to Oosting *et al.* (2014), many contextual reasons make livestock in the tropics absolutely different from the Western world. The specificity and complex nature of livestock in the tropics makes the type "tropical livestock" a relevant subject within the animal production.

Therefore, the aim of this study was to evaluate the effect of dimension and ecological zone on the performance of Dual Purpose farms in the Mexican tropic region, considering technical, productive and social characteristics. Thus, offering adequate

pathways to enhance their viability on a long-term basis.

Material and methods

Study area

The study area was the Mexican tropic divided into two ecological zones: dry tropic (DT) and wet tropic (WT) (INEGI, 2013). DT is characterized by having an extended drought period that varies between five and nine months and 1,200 mm of rainfall; the rainy season usually begins in May and finishes in August. The weather is warm and the predominant vegetation is tropical, deciduous forest and savannas. The DT covers around 40 million hectares and it is located from the centre north to southeast of Mexico. WT presents high temperatures and over 1,200 mm of rainfall distributed throughout the year. The dominant ecosystem is tropical forest, savannas and wetlands; WT has around 22 million hectares and it is mainly located in the south, southeast and, to a lesser extent, in the central and northern areas of Mexico (INEGI, 2013).

Population, sample and data collection

The dual-purpose cattle are mainly located in tropics although they present a heterogeneous distribution (Díaz-Rivera *et al.*, 2011). According to Albarrán-Portillo *et al.* (2015), there are more than 372,000 farms of DP in Mexico. This research was focused on DP farms with 50 or less cows in both dry and wet areas from tropic regions of Mexico (90% of the population). A representative sample of 3,285 farms was collected from smallholder beneficiaries of the "Livestock Technical Assistance Program" from Department of Agriculture (SAGARPA) (0.97% of DP farms). Data collection was carried out through a structured questionnaire designed by experts from National Institute of Forestry, Agriculture and Livestock Research (INIFAP), according to FAO (2008) methodology; it was composed by 184 items covering technical, productive and social features.

The DP farms were classified by their dimension (number of cows) and ecological zone (wet and dry tropics) (Lentés *et al.*, 2010). Regarding dimension, the farms were grouped into three levels according to the number of total cows per farm: very small farms (from 1 to 9 cows), small farms (10-19 cows) and medium farms (20-50 cows). The three groups presented significant differences regarding herd size ($p \leq 0.001$) according to ANOVA and Student–Newman–Keuls

(SNK) method. Sixty seven percent of the farms were located in DT and the rest in WT.

Selection of variables and statistical analysis

The selection of variables was done through participative methodology proposed by Torres *et al.* (2014) and García-Martínez *et al.* (2016). First, relevant variables were identified in the literature and second, final variables were selected by a group of 14

experts composed by researchers and livestock service providers. The variables had to be representative of DP farms, easy to collect, reliable, consistent and presented high variability (coefficient of variation over 60%). Spearman partial correlation was calculated to remove one of each pair of those highly correlated ($r > 70\%$).

Subsequently, the experts' group selected 27 variables by consensus, 14 metrics and 13 non-metrics, each of them were described in Tables 1 and 2, respectively (FAO, 2008).

Table 1. Effect of herd size and ecological zone on farms (means \pm standard error)

Variables	Total	Dimension (A)			Ecological zone (B)		Significance		
		Very small ¹	Small ²	Medium ³	Dry tropic	Wet tropic	A	B	A×B
Number of farms (%)	3285	959 (29.2)	1169 (35.6)	1157 (35.2)	2187 (67)	1098 (33)			
Technical items									
Grazing surface (ha)	23.5 \pm 0.8	11.7 \pm 3.5 ^c	21.6 \pm 3.0 ^b	34.3 \pm 3.0 ^a	23.6 \pm 2.1	21.5 \pm 3.0	***	n.s.	**
Total animal units (AU)	30.9 \pm 0.4	14.0 \pm 0.4 ^c	25.5 \pm 0.4 ^b	52.1 \pm 0.4 ^a	28.6 \pm 3.0	32.5 \pm 0.4	***	***	*
Total herd (heads)	44.0 \pm 3.1	17.6 \pm 5.7 ^c	33.1 \pm 5.2 ^b	76.9 \pm 5.2 ^a	42.5 \pm 3.8	42.7 \pm 5.4	***	n.s.	n.s.
Stocking rate (AU/ha)	1.1 \pm 0.0	1.2 \pm 0.1 ^a	1.1 \pm 0.1 ^a	0.9 \pm 0.1 ^b	1.2 \pm 0.1	0.9 \pm 0.1	***	***	*
Productive items									
Milk yield (L/farm/year)	7669.7 \pm 229.7	3257.4 \pm 1693.1 ^c	6295.7 \pm 1462.5 ^b	11,492.9 \pm 1473.3 ^a	8358.0 \pm 1018.3	5674.6 \pm 1457.1	***	***	***
Milk per cow (L/cow/year)	464.1 \pm 10.9	472.8 \pm 21.9 ^a	471.7 \pm 18.9 ^a	379.2 \pm 19.0 ^b	516.3 \pm 13.5	366.2 \pm 18.9	***	***	n.s.
Calves (heads)	4.9 \pm 0.1	3.4 \pm 1.1 ^c	4.5 \pm 1.0 ^b	6.6 \pm 1.0 ^a	4.9 \pm 0.7	4.78 \pm 1.0	***	n.s.	***
Unproductive animals (heads)	2.1 \pm 0.1	2.2 \pm 0.9	1.9 \pm 0.8	2.3 \pm 0.8	2.2 \pm 0.5	2.2 \pm 0.8	n.s.	n.s.	***
Cheese yield (kg)	148.6 \pm 10.6	53.9 \pm 29.7 ^c	129.42 \pm 25.6 ^b	205.1 \pm 25.8 ^a	174.2 \pm 84.7	84.8 \pm 25.6	***	***	n.s.
Milk yield per worker (L/w)	5207.3 \pm 171.0	2,410.2 \pm 1142.7 ^c	4,659.17 \pm 987.1 ^b	7172.82 \pm 994.3 ^a	5742.7 \pm 687.3	3752.1 \pm 983.5	***	***	***
Milk production per ha (L/ha)	560.37 \pm 32.5	597.3 \pm 76.5	551.7 \pm 51.6	538.5 \pm 42.3	546.8 \pm 38.6	587.4 \pm 59.5	n.s.	n.s.	n.s.
Social items									
Age (years)	51.4 \pm 0.2	50.2 \pm 0.2 ^b	50.9 \pm 0.1 ^b	52.6 \pm 0.2 ^a	51.7 \pm 0.1	50.6 \pm 0.2	***	n.s.	n.s.
Economics dependents (n)	2.9 \pm 0.0	2.7 \pm 0.1 ^b	2.9 \pm 0.1 ^a	3.1 \pm 0.1 ^a	3.0 \pm 0.1	2.9 \pm 0.1	***	n.s.	n.s.
Employments (UW ⁴)	1.9 \pm 0.0	1.6 \pm 0.2 ^b	1.7 \pm 1.1 ^b	2.2 \pm 0.01 ^a	1.8 \pm 0.0	1.9 \pm 0.0	***	n.s.	n.s.

¹1 to 9 cows. ²10 to 19 cows. ³20 to 50 cows. ⁴UW: Unit of work. ^{a,b,c} Values with different letters are significant; ns, *, **, ***: $p > 0.05$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

Descriptive statistics of the system were carried out, and subsequently dimension and ecological zone effects were evaluated using the general linear model (GLM) with two factors and their interactions, following a hierarchical model, where ecological zone was nested to dimension. When a significant effect was detected, least square means were compared using the Student-Newman-Keuls's test. Chi-square tests and contingency tables were used to determine associations between non-metrics variables. When significant effects were found, Z test was applied adjusted with Bonferroni method (Toro-Mujica *et al.*, 2015). All statistical analyses were performed with SPSS 11.5.

Results

Typical farm of Dual Purpose system in the Mexican tropic region

Descriptive statistics and frequency analyses are shown in Tables 1 and 2, respectively. Sixty five percent of the farms were very small and small, with less than 20 cows. The typical farm had 23.5 ha of land, 68.5% of the ownership was “*Ejido*” (communal land used for agriculture and livestock with communal holdings and individual farm parcels). The average herd consisted of 44 heads (cows, unproductive animals, sires, replacement cows, calves, etc.), and 1.1 animal unit (AU) per hectare of stocking rate. This typical farm produced annually 7,670 L of milk, 148 kg of cheese and sold 4.9 calves on average. The milk yield was 464 L/cow, 5,207 L/worker and 560 L/ha. Each farm generated on average 1.9 units of work (UW) and 2.9 people depended directly on the farm (Table 1).

Animal feeding was mainly based on grazing of native pastures, although a 34.7% of the smallholders used cultivated pastures, crop residues (44%) and other local resources of the system as stubble (Table 2). DP smallholders used cultivated pastures and crops, such as *Panicum maximum*, *Brachiaria brizantha*, *Andropogon gayanus*, *Hypparrheina rufa*, *Digitaria decumbens*, *Cynodon pectostachyus*, *Cynodon dactylon*, *Pennisetum* sp., *Saccharum officinarum*, *Zea mays* and *Sorghum* sp. Sometimes, DP smallholders mixed the diet with legumes such as *Clitoria ternatea* and *Leucaena leucocephala*. Also, 47% of them used hay making, 28.2% green fodder (cut and brought directly to animals) and 19.5% used silage in drought season. Occasionally, the smallholders' utilized concentrate supplements or processed feed and 65% incorporated mineral salt as a supplement.

Dimension and ecological zone effect

The results of general linear model (GLM) and chi-square tests are shown in Tables 1 and 2, respectively. A strong effect was found relating to dimension in 12 of 14 metric variables ($p < 0.001$). The ecological zone effect was detected in 7 out of 14 variables ($p < 0.05$), mainly in productive and social variables. Moreover, seven significant interactions were identified in technical and productive variables.

The production variables showed an effect of economy of scale. So, when dimension increased, the milk per farm yield was increased too, but not for the productivity index, which was higher in very small farms; such as stocking rate and milk per cow ($p < 0.001$) variables.

DT showed a higher technological level in milk production than WT, with differences associated to productive variables such as stocking rate, milk yield, milk per cow, cheese yield and milk yield per worker ($p < 0.001$). On the contrary, WT farms showed higher levels of total animal units in the herd ($p < 0.001$).

The non-metric variables' results are shown in Table 2. Significant differences were found in ten variables of dimension and other ten of ecological zone, especially in social items. The “*Ejido*” land ownership was greater than the private land owned (68.5% vs 31.5%), with dimension effect ($p < 0.001$) but independent of the ecological zone. This way, when farm size increases, the private land owned increases too. Less than 35% of farms used cultivated pastures, silage, and green fodder, although significant differences were found for both dimension and ecological zone ($p < 0.05$). The use of crop residues presented a middle level (>40%) and hay use was moderately influenced by dimension and ecological zone ($p < 0.05$).

DP responds to a meat-milk system, where 86% of the smallholders affirmed having sold some kind cattle the previous year and 50% of the farms reported not having sold milk the previous year. Milk production was derived to feed suckling calves, family consumption and, in 16% of farms, to produce and sell cheese. This situation was associated with the ecological zone, presenting higher levels of dairy milk sold in DT than in WT ($p < 0.001$) (Table 2).

In Table 2, the results showed that 72% of the farms were located at marginalized levels from medium to very high, with significant differences both in dimension ($p < 0.05$) and ecological zone ($p < 0.001$); this effect was higher in WT (over 90%). In relation to farm incomes, livestock production was the exclusive economic activity developed by 41% of DP smallholders and 78.6% affirmed that DP was the main source of income, with important differences

Table 2. Frequencies (%) and Chi square test according to herd size and ecological zone

Variables	Total	Dimension ¹			Significance ²	Ecological zone ¹		Significance ²	
		Very small	Small	Medium		Dry tropic	Wet tropic		
Number of farms (%)		959 (29.2)	1169 (35.6)	1157 (35.2)		2187 (67)	1098 (33)		
<u>Technical items</u>									
Land ownership									
	Private	31.5	27.9 ^b	30.3 ^b	35.6 ^a		30.4	33.7	
	Ejidal	68.5	72.1 ^a	69.7 ^a	64.4 ^b	***	69.6	66.3	n.s.
Grazing									
Cultivated pastures	No	65.3	73.0 ^a	66.8 ^b	57.3 ^c		61.3 ^b	73.2 ^a	
	Yes	34.7	27.0 ^c	33.2 ^b	42.7 ^a	***	38.7 ^a	26.8 ^b	***
Grazing crop residues	No	55.6	59.1 ^a	52.8 ^b	55.7 ^{ab}		41.6 ^b	83.6 ^a	
	Yes	44.4	40.9 ^b	47.2 ^a	44.3 ^{ab}	*	58.4 ^a	16.4 ^b	***
Roughage³									
Silage	No	80.5	83.8 ^a	80.1 ^{ab}	78.1 ^b		82.3 ^a	77.0 ^b	
	Yes	19.5	16.2 ^b	19.9 ^{ab}	21.9 ^a	**	17.7 ^b	23.0 ^a	***
Hay	No	53.0	55.6 ^a	49.9 ^b	54.1 ^{ab}		40.3 ^b	78.4 ^a	
	Yes	47.0	44.4 ^b	50.1 ^a	45.9 ^{ab}	*	59.7 ^a	21.6 ^b	***
Green fodder	No	71.8	75.2 ^a	71.2 ^{ab}	69.5 ^b		70.9	73.5	
	Yes	28.2	24.8 ^b	28.8 ^{ab}	30.5 ^a	*	29.1	26.5	n.s.
<u>Productive items⁴</u>									
Milk sold	No	50.4	52.3	49.3	49.9		44.7 ^b	61.7 ^a	
	Yes	49.6	47.7	50.7	50.1	n.s.	55.3 ^a	38.3 ^b	***
Cattle sold	No	13.3	13.5	13.4	13.1		13.4	13.1	
	Yes	86.7	86.5	86.6	86.9	n.s.	86.6	86.9	n.s.
Cheese sold	No	83.8	85.9	83.7	82.1		79.6 ^b	92.1 ^a	
	Yes	16.2	14.1	16.3	17.9	n.s.	20.4 ^a	7.9 ^b	***
<u>Social items</u>									
Gender									
	Male	88.3	85.3 ^b	89.1 ^b	90.1 ^a		89.6 ^a	85.8 ^b	
	Female	11.7	14.7 ^a	10.9 ^b	9.9 ^b	**	10.4 ^b	14.2 ^a	*
Farmer education									
	Illiterate	25.7	23.7	26.2	26.8		31.7 ^a	13.7 ^b	
	Basic	69.5	72.8 ^a	68.9 ^{ab}	67.3 ^b		66.1 ^b	76.2 ^a	
	Intermediate	4.8	3.5 ^b	4.9 ^{ab}	5.9 ^a	*	2.2 ^b	10.1 ^a	***
Farm income ⁵									
	Higher than 90	40.8	30.2 ^c	41.1 ^b	49.4 ^a		34.4 ^b	53.6 ^a	
	51 to 90	37.8	44.7 ^a	34.0 ^b	35.9 ^b		39.2 ^a	35.0 ^b	
	Less than 50	21.3	25.0 ^a	25.0 ^a	14.7 ^b	***	26.4 ^a	11.4 ^b	***

Table 2. Continued

Variables	Total	Dimension ¹			Significance ²	Ecological zone ¹		Significance ²
		Very small	Small	Medium		Dry tropic	Wet tropic	
Marginalization								
Very high	5.6	4.8	5.7	6.1		1.3 ^b	14.1 ^a	
High	20.0	22.1	19.4	18.9		11.7 ^b	36.6 ^a	
Medium	47.3	46.9	49.4	45.5		50.7 ^a	40.6 ^b	
Low	13.4	11.5	13.6	14.7		16.2 ^a	7.7 ^b	
Very low	13.7	14.7	11.8	14.8	*	20.1 ^a	0.9 ^b	***

¹Different letters between columns ($p < 0.01$), ²Significant differences between rows (Chi square test, ns, *, **, ***: $p > 0.05$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively), ³ It refers to the technical items that smallholders could do or not last year, ⁴ It concerns to the products sold or not last year in the farm, ⁵ % of total annual farm incomes

associated to both factors ($p < 0.001$). As the dimension increased, the farm's specialization increased too and the percentages of livestock farm incomes were higher. In 88% of WT farms, livestock was the main activity ($p < 0.001$). Most of the farm owners were men (88%) and the farmer's educational level was very low, 95% of them were illiterate or have received just basic education. The highlighted social variables were gender and farmer education; both variables were associated significantly with dimension and ecological zone ($p < 0.05$); Very small farms showed higher frequency in variables corresponding to women owners and higher level of education for WT ($p < 0.001$).

Table 1 shows the main results of interactions between dimension and ecological zone on productive variables: Factors' interactions enhanced the effect of specialization in milk production by intensification in DT farms (dairy herd), with higher values in stocking rate, milk yield and milk yield per worker. In the opposite side, WT farms were more specialized in meat-milk production (beef herd), with higher levels in total animal units, calves, and unproductive animals.

Discussion

This study evaluated the effect of dimension and ecological zone on the performance of DP farms in the Mexican tropic region. The results are important since they provide valuable information in order to enhance their viability on a long-term basis.

The typical farm of DP in the Mexican tropic region previously described, showed similarities with those defined for FAO (2008), Vilaboa-Arroniz & Díaz-Rivera (2009), Díaz *et al.* (2011) and Cortés-Mora *et al.* (2014). DP is a mixed system with several integrated productive activities, low external inputs,

with synergies among crops, forest and adapted breed animals to marginal conditions, with low stocking rate, low productive levels and trading of beef (calves) and milk. Moreover, DP is based on grazing native pasture and on crop residues of low nutritional values. Grazing is developed on land not suitable for agriculture with slopes greater than 20% (Albarrán-Portillo *et al.*, 2015). The average smallholders' age was 51 according to Cuevas-Reyes *et al.* (2013) and Albarrán-Portillo *et al.* (2015). Also, the older farmers have gained greater financial capability and dimension but these items were not related to an improvement of the productive index in this study. Our results showed that DP in the Mexican tropic region generates on average 1.9 UW and 2.9 people depend directly on livestock. Both variables are related to dimension but are independent to ecological zone, similar to what is indicated by Cuevas-Reyes *et al.* (2013, 2015) in DP and the family-based farms of Cortés-Arriola *et al.* (2015). This result explains the social importance in marginalized territories of this system. It generates self-employment opportunities to a considerable amount of smallholders, supports the family capitalization and encourages the ability to retain the functionality of providing livelihood to families in times of perturbation.

As observed in the present study, the dimension determines the productive structure of the farm and within each dimension stratum, the ecological zone and interactions between factors, determine the productive orientation (milk or calves).

These results showed that when the dimension was increased, the specialization level for producing only meat (calves) or milk was higher, but the level of diversification of other productive activities was reduced from 70% in the very small to 50% in medium farms (Table 2), according to Toro-Mujica *et al.* (2011) and Cortés-Arriola *et al.* (2015). Very small farms, with fewer land surfaces (11.7 ha) were more diversified in

order to satisfy their market participation and needs for food, whereas larger farms were more specialized and less diversified. This is the case of Zacazonapan farms, which are specialized in milk production and calves due to available local markets (García-Martínez *et al.*, 2015). Small and medium farms of WT, similarly to what Valdovinos *et al.* (2015) described, showed a higher potential to use green fodder, while DT farms utilized hay making as forage according to Cuevas-Reyes *et al.* (2013).

DT farms were specialized in milk, while WT farms were mainly oriented to calves. Fifty percent of the smallholders did not sell milk the previous year. This decision was independent of dimension and it was conditioned by ecological zone; WT was the zone that showed the highest percentage of smallholders who did not sell milk ($p < 0.001$). These results could indicate the need for deepening the knowledge of smallholders productive logic as their reason for being, their important role in satisfying the food supply and the desire for reducing the vulnerability of risk to poverty (Oosting *et al.*, 2014; Torres *et al.*, 2015). This way, García-Martínez *et al.* (2016) indicate that only 15% of the DP smallholders present commercial objectives and Díaz-Rivera *et al.* (2011) found only 8%.

The main kind of land ownership (68%) was communal regime (Ejido). This situation could limit the implementation of technologies, investment and new improvements (Albarrán-Portillo *et al.*, 2015; Cuevas-Reyes *et al.*, 2016). In this regard, results agreed with Angón *et al.* (2013) showing that if the dimension grows, the private ownership land has to increase and it could imply the spread of a spatial competitive relationship with the other activities of the farm (crops, forest, and other land use).

Large-scale farms generate various effects; Steinfeld *et al.* (2006), Gerber *et al.* (2013) and Angón *et al.* (2015) suggest that when farms are more specialized in both dimension and intensification tend to increase production volumes, herd size, and productivity, but the number of farms in the territory was significantly reduced. In this regard Udo *et al.* (2011) and Oosting *et al.* (2014) indicated that a considerable part of the smallholders in a village would not be part of the development; some of them will have to become labourers in their community or migrate to urban areas to find employment as effects of increased dimension in long term ("stepping out" strategy by Dorward *et al.*, 2009). This situation leads us to question on what the real employment and income alternatives are for most of the smallholders older than 50, with very low levels of education and skills in case they must leave the activity.

DP system needs improvements, although it is important to analyse if the increase of scale and

intensification in the tropics are a viable solution for development or if there are other options more suitable and feasible. According to Gerber *et al.* (2013) animal management practices and technologies determine the level of productivity. Angón *et al.* (2015) propose improving technological practices in the grazing dairy system in La Pampa (Argentina). Oosting *et al.* (2014) recommend increasing the production and shift from rural to urban market and Cuevas-Reyes *et al.* (2013) highlight that the clustering and a major organization of smallholders could be an access to a pathway of higher added value. Beuchelt *et al.* (2015) suggest developing low-cost sustainable technologies on crop residues and López-i-Gelats *et al.* (2015) recommended the adoption of new multifunctional rural development strategies.

Therefore, different points of view should be considered in the studies on DP, including both technical factors (*e.g.* Amankwah *et al.*, 2012; Sumberg & Lankonandé, 2013; Torres *et al.*, 2015), and socioeconomic ones (*e.g.* Bernués & Herrero, 2008; Lentés *et al.*, 2010; Cuevas-Reyes *et al.*, 2013; Albarrán-Portillo *et al.*, 2015). Besides, in the European Union a new disruptive concept called "bioeconomy" appears, as a sustainable model of growth to combine continued wealth generation and employment with bio-based sustainable resource usage (Philippidis *et al.*, 2014).

DP should be examined at multiple dimensions by analyzing and linking macro- and micro-level drivers. Besides, Udo *et al.* (2011) and Poole *et al.* (2013) seek a transversal holistic approach (actionable and scientific knowledge) through consensus methodology and the participation of different stakeholders: farmers, development agents, researchers, producer's organizations, local and national public institutions. It is also essential to address the innovation process, by providing better levels of training and an effective technical support from public and private Institutions (*i.e.* industry, farmers' organizations, value channels, investment).

In conclusion, DP in Mexican tropical region is a multifunctional and diversified system, highly influenced by dimension, ecological zone and the interactions between both factors. Dimension determines production level and productive structure; meanwhile, ecological zone and the interactions lead to the specialization in milk, meat or both. When there was an increment of size, the production increased too, although this did not necessarily imply the achievement of higher levels of productivity index. The smallholders should enhance technological adoption in feeding, land use, and production process into the tropical conditions context (best practices), associated with an improvement of education level. Subsequently,

dimension and intensification could improve the productive specialization.

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