Trop Anim Health Prod
DOI 10.1007/s11250-015-0846-z

REGULAR ARTICLES

Assessment of the sustainability of dual-purpose farms by the IDEA method in the subtropical area of central Mexico

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Received: 5 September 2014 / Accepted: 30 April 2015

Abstract The objective of this study was to assess the sustainability of 10 dual-purpose cattle farms in a subtropical area of central Mexico. The IDEA method (Indicateurs de Durabilité des Exploitations Agricoles) was applied, which includes the agroecological, socio-territorial and economic scales (scores from 0 to 100 points per scale). A sample of 47 farms from a total of 91 registered in the local livestock growers association was analysed with principal component analysis and cluster analysis. From results, 10 farms were selected for the in-depth study herein reported, being the selection criterion continuous milk production throughout the year. Farms had a score of 88 and 86 points for the agroecological scale in the rainy and dry seasons. In the socio-territorial scale, scores were 73 points for both seasons, being the component of employment and services the strongest. Scores for the economic scale were 64 and 56 points for the rainy and dry seasons, respectively, when no economic cost for family labour is charged, which decreases to 59 and 45 points when an opportunity cost for family labour is considered. Dual-purpose farms in the subtropical area of central Mexico have a medium sustainability, with the economic scale being the limiting factor, and an area of opportunity.

Keywords Agroecological · Socio-territorial · Economic · Sustainability · Assessment

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Introduction

The concept of sustainable development was defined in the report by the Brundtland Commission as "development that meets the needs of the present without compromising the ability of future generation to meet their own needs" (UN 1987), a holistic concept constructed on three pillars: environmental or agroecological, socio-territorial and economic (Vilain et al. 2008); it has been applied more frequently in the assessment of agriculture and animal production systems, given the concerns on natural resources deterioration (Altieri 1994).

Vilain et al. (2008) state that any economic activity in order to be sustainable must be ecologically sound, socially just and economically viable. Sustainability must be understood as a changing social construct in accordance with society demands, taking into consideration specific formulations for each geographical site and production context (Zahm et al. 2008).

There is a need to assess the sustainability of farming systems in order to identify areas of weakness and opportunities for improvement that may inform interventions, research and policies (Fadul-Pacheco et al. 2013).

Dual-purpose systems (milk/beef) are located in the tropical areas of the country under 1600 m of altitude both in the Gulf of Mexico as in the Pacific slope. This system contributes with 16 % of national milk production, representing 44 % of milk-producing farms in the country (FIRA 2010). Given the benefits that the sale of milk brings to rural families, dairy farming in Mexico has been considered as an option to ameliorate rural poverty (Espinoza-Ortega et al. 2007).

In general, dual-purpose farms are considered as unproductive and inefficient from a "productivist" stand point; however, the low use of external inputs and the utilization of local resources for production may make these farms sustainable in economic, agroecological and socio-territorial terms throughout the year.

Published online: 10 May 2015

Fadul-Pacheco et al. (2013) assessed the sustainability of small-scale dairy farms in a temperate area in the highlands of central Mexico, concluding that the economic scale was the weak area in these systems, caused mainly by the high dependency on external feed inputs. The agroecological scale in those systems obtained the highest score (59/100), while the socio-territorial scale was intermediate.

The objective of this work was to assess the sustainability of dual-purpose cattle farms applying the IDEA method.

Materials and methods

Description of the study area

The study was undertaken in the municipality of Zacazonapan, located in the southwest of the State of Mexico, at 19° 04′ 48″ North and 100° 13′ 18″ West, and an altitude of 1470 m. Main climate is subtropical (warm subhumid), with a mean annual temperature of 23 °C, mean maximum of 31 °C, mean minimal of 15 °C, and mean annual rainfall around 1115 mm in marked rainy (June to early November) and dry (December to May) seasons.

Cattle production is developed in 69 % of the municipality (SAGARPA 1997), with a traditional dual-purpose system typical of these regions. The landscape is formed by hills and slopes. Farm sizes range from 14 to 450 ha; and herd sizes between 30 and 80 head mostly comprising zebu and their crosses with Brown Swiss, which have proved to be well adapted to the region (Albarrán-Portillo et al. 2015).

Extensive grazing of pastures dominated by African Star grass (*Cynodon plectostachyus*) is the basis for feeding herds in the rainy season, with an average of 70 % of the farm surface sown to this grass. Maize is grown for grain production in whatever arable land is available. In the dry season, the availability and quality of forages are low, so that farmers supplement their livestock, mainly milking cows, based on local resources as are the maize cobs or grain from their home-grown crop or bought-in compound feeds.

The study was undertaken during the rainy season of 2012 (July to November) and the dry season of 2013 (December 2012 to June 2013).

Selection of farms

There are 91 farms registered in the local livestock growers association, from which a sample of 47 farms was taken (Hernández et al. 2004), and a survey applied to farmers with the objective of determining the socioeconomic characteristics, resources and infrastructure available and the general management of their farms (Vilaboa-Arroniz et al. 2009). Data was analysed by multivariate methods (Hair et al. 2006). Firstly, a principal component analysis was performed, from which a cluster analysis was undertaken, utilizing the coordinates of the original variables in the resulting factors (García-Martínez et al. 2008).

This process identified four clusters related to (1) structure, (2) size, (3) management and (4) productive orientation (milk, beef-milk, beef), which accounted for 83 % of accumulated variance ($P<0.05$) and a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.65 (Hair et al. 2006; Pérez 2005). Pérez (2005) mentions that KMO values between 0.5 and 0.75 are acceptable to validate the analysis.

Differences among clusters were related to farm size, management, productive orientation and origin of incomes. From that, this in-depth study was focused on those farms that do milk cows year round, and milk sales represent most of the family income.

The IDEA method version 3 was applied (*Indicateurs de Durabilité des Exploitations Agricoles*) (Vilain et al. 2008), as it was the case in the work reported by Fadul-Pacheco et al. (2013). The method is structured with 17 objectives that constitute the three scales of sustainability: agroecological, socio-territorial and the economic scales. Each scale is divided in 3 or 4 components (3 for each one of the agroecological and socio-territorial scale and 4 for the economic scale), summing up 10 components, which are integrated by 42 indicators (18 for each one of the agroecological and socio-territorial scales and 6 for the economic scale) (Table 1). The objectives are coherence, autonomy, biodiversity, landscape protection, soil protection, protection and water, atmosphere, no renewable resources, animal welfare, product quality, ethics, human development, local development, quality of life, citizenship, adaptability and employment.

The method weighs the indicators in a similar manner as those used by Van Passel et al. (2007), Van Cauwenbergh et al. (2007) and Meul et al. (2008). Each indicator has a maximum score, and each scale can add up to 100 points. The sustainability value is given by the lowest score of the three scales (Vilain et al. 2008), following the rule of the limiting factor put forward in ecosystem dynamics (M'Hamdi et al. 2009).

Some modifications were undertaken in order to adapt the IDEA method to the specific Mexican context of dual-purpose farms. Indicator B1 "milk composition" was done following the official Mexican standard for raw milk (NMX-F-700-COFOCALEC-2004). Indicator A14 concerning pesticide use, the weights proposed by the IDEA method were used but taking account of specifications by the Mexican National Institute of Ecology (Instituto Nacional de Ecología 1991), and lastly, economic indicators C1 and C5 were determined in accordance to the minimal wages prevalent in the study area during the collection of information.

Besides those adaptations, 4 of the 42 indicators were not included in the assessment of sustainability because they were not applicable or information was not sufficient to estimate a score. These were two indicators from the agroecological

Table 1 Summary of scales, components and indicators of the IDEA method

Scales	Components	Indicators	
Agroecological	Diversity	4	Diversity of annual and temporary crops, diversity of perennial crops, animal diversity and animal biodiversity
	Organization of space	7	Crop rotation, dimension of fields, management of organic waste, ecological buffer zones, contribution to environmental challenge of the territory, improvement of the space and fodder area management
	Farming practices	7	Fertilization, manure management, pesticides, veterinary products, soil protection, water management and energy dependency
Socio-territorial	Quality of products and the land	5	Quality process, valorisation of the building patrimony and landscape, non-organic waste management, access to the property and social involvement
	Employment and services	6	Short trade value chains, autonomy and enhancement of local resources, services and multiple activities, contribution to employment, collective work, probable farm sustainability
	Ethics and human development	7	Dependence on commercial concentrates, animal welfare, training–education, labour, intensity, quality of life, isolation, quality of buildings
Economic	Viability	2	Economic viability and economic specialization rate
	Independence	2	Financial autonomy, sensibility to government subsidies
	Transferability	1	Transferability
	Efficiency	1	Efficiency of the productive process

scale (enhancement and conservation of genetic heritage and measures to protect the natural heritage) and two indicators of the socio-territorial scale (enhancement of buildings and landscape heritage and services—multiactivities).

A semi-structured questionnaire was applied by direct interview to farmers from the cluster of farms that do milk cows year round to collect information. Also, farms were visited every month to collect follow-up information on productive records of farms as well as any other information relevant to the IDEA method.

Milk analyses

Milking in these systems is by hand once a day, between 5:00 and 9:00 hours in the morning. Samples were taken individually from each cow, directly from the milk bucket when milking each cow was finished, taking one sample per cow per month at each of the 10 farms. Milk composition (fat, protein, lactose and added water (g/kg)) was analysed within 3 h of sampling with a portable ultra-sound Lactoscan Milk Analizer®.

Results

Agroecological scale

Table 2 shows the scores for each indicator in the agroecological scale by season. In general, there were small differences on the total score between rainy and dry seasons.

In the diversity component, there was a higher score in the rainy season given the diversity of annual or temporary crops that are cultivated in the available arable land, compared to the dry season where there are basically no annual crops, such that they represent only 1 % of the arable area available (0.2 ha) in this season.

Scores in the organization of the space component were near the maximum scores, with slightly higher values for the dry season compared to the rainy season, since 99 % of the land is used to graze the herd.

In the farming practices component, recorded scores for almost all indicators in both seasons were the maximum possible, except for the veterinary products indicator which has a null score (undesirable performance), since there is a high usage of veterinary products in both seasons.

Socio-territorial scale

The score in the socio-territorial scale was the same for both seasons (73 out of 100), since all indicators do not change across seasons (Table 3).

In terms of employment and services, the indicator of short trade obtains the highest possible score since the trading chain has only two or three links. On average, 79 % of milk produced was sold to small cheese-making workshops, 18 % is made into cheese by the farmers themselves and only 3 % was sold as fluid raw milk directly to consumers.

Dual-purpose farms provide permanent and temporary employment at farm/production level and indirect employment at the marketing level through cheese manufacturing. Cheese manufacturing gives social vitality to the territory of Zacazonapan as evidenced by the high esteem attached to the artisan-made genuine Mexican cheese (Cervantes-Escoto et al. 2013).

In terms of transferability, in 50 % of the farms, at least one of the family members (sons) expressed their intention to take

Table 2 Scores for the agroecological scale

Component	Indicators	Mean farm scores		Maximum possible score
		Rainy season	Dry season	
Diversity	Biodiversity of annual or temporary crops	5	0	14
	Biodiversity of perennial crops	11	11	14
	Animal biodiversity	8	8	14
Organization of space	Crop rotation	6	8	8
	Dimension of fields	4	6	6
	Management of organic waste	5	5	5
	Ecological buffer zones	9	9	12
	Improvement of the space	4	5	5
	Fodder area management	2	2	3
Farming practices	Fertilization	8	8	8
	Manure management	3	3	3
	Pesticides	11	13	13
	Veterinary products	0	0	3
	Soil resource protection	5	5	5
	Water resource management	4	4	4
	Energy independence	8	8	10
	Total	88	86	100

over the family farm or is already working in the farm. On average, there are four sons and a daughter living in the farm, and the average age of farmers was 53 years old.

Limiting factors in this scale are the quality of produced milk since farmers do not have optimal hygienic conditions for milking and handling milk (proper infrastructure, cooling tanks, processing equipment). Another limiting aspect is in the organization for collective work. In general, farmers had little interest to form groups or associations in order to obtain benefits from government support schemes.

Table 3 Scores for the socio-territorial scale

Component	Indicators	Mean farm scores		Maximum possible score
		Rainy season	Dry season	
Quality of the products and the land	Quality of milk	4	4	10
	Non-organic waste management	2	2	5
	Access to the property	5	5	5
	Social involvement	6	6	6
Employment and services	Short trade	7	7	7
	Autonomy and enhancement of local resources	10	9	10
	Contribution to employment	5	6	6
	Collective work	1	1	5
	Probable farm sustainability	3	3	3
Ethics and human development	Dependence on commercial concentrates	10	10	10
	Animal welfare	2	2	3
	Training–education	5	5	6
	Labour intensity	2	2	7
	Quality of life	4	4	6
	Isolation	3	3	3
	Quality of buildings	4	4	4
	Total	73	73	100

Economic scale

In general terms, farms were economically viable, having the highest score on financial viability (15/15). However, they scored 1 out of 20 points on the transferability indicator (Table 4).

Table 5 shows the total cost of production per litre of milk as well as the cost of production per kilogram of beef live weight (sold on the hoof at farm gate). The latter is calculated from the sale of bull calves sold before 18 months of age, animals sold as breeding stock, or culled animals, under the two studied scenarios.

In relation to the cost of production of beef in the rainy season, when family labour is excluded, production costs are US$0.93 per kilogram live weight, but when an opportunity cost for family labour is included, it increases to US$1.34 (44 % more). In the dry season, if an opportunity cost for family labour is included, the cost of production is 25 % higher than the sale price, incurring in a loss.

Discussion

The overall score of sustainability for the dual-purpose cattle farms assessed was 73/100 points being higher than those reported by Bir et al. (2011) (56/100), Fadul-Pacheco et al. (2013) (52/100) and M'Hamdi et al. (2009) (57/100). Authors mentioned above evaluated the sustainability of dairy farms in semiarid (Bir et al. 2011; M'Hamdi et al. 2009) and temperate subhumid (Fadul-Pacheco et al. 2013) conditions, being probably the reason why they scored lower than dual-purpose farms under the semitropical conditions reported here.

Dual-purpose farms assessed had a score of 73/100 points in the socio-territorial scale which is also considered high. However, the sustainability of these farms is determined by the economic scale that has the lowest score (60/100), the same limiting scale as reported by Fadul-Pacheco et al. (2013) (43/100). On the contrary, the socio-territorial scale was the limiting factor for the dairy systems evaluated in North Africa countries (Bir et al. 2011; M'Hamdi et al. 2009).

The agroecological scale was the scale with the highest scores in this study (87/100), same as the reports by Bir et al. (2011) (64/100), Fadul-Pacheco et al. (2013) (59/100) and M'Hamdi et al. (2009) (60/100), implying good indicators in diversity, organization of space and farming practices.

Biodiversity of crops, animals and products in the agroecological scale is very important, since for example the by-products (dung and urine) of one component may be inputs or production factors in other components (crops, soil) (Parsons et al. 2011; Vilain et al. 2008).

One of the most notable strengths of these systems is the diversity of perennial crops, since 80 % of the farm areas are tropical grasslands (grasses, shrubs and trees), in what is considered an extensive system, having a low impact to the environment, unlike agriculture (Hayo et al. 2002; Espinosa-García et al. 2004).

Sylvo-pastoral areas with a low density of trees do have a positive impact on animal production over the years (Yamamoto et al. 2007), providing nutritive browse to cattle particularly during the dry season. On the other hand, cattle contributes to the regeneration and natural propagation of plant species, grasses and legumes (Olivares-Pérez et al. 2013).

Another benefit from cattle is that excreta deposition falls directly on the soil, representing an organic fertilization and a reduction of external fertilizer inputs (Pimentel and Kounang 1998). Maize crops are grown on minimal tillage, mostly due to the slope and characteristics of soil and fields, helping to reduce erosion up to 80 % and runoff in up to 45 % (Tapia et al. 2002). These advantages are reflected in more than one of the evaluated indicators in the agroecological scale that directly or indirectly do have an effect on the economic scale, mainly by reducing feeding and fertilization costs particularly during the rainy season.

Table 4 Scores in the economic scale under scenarios with and without an opportunity cost for family labour

Economic scale	Rainy season		Dry season		Maximum possible score
	Including cost of FL	Excluding cost of FL	Including cost of FL	Excluding cost of FL	
Economic viability	17	18	11	16	20
Economic specialization rate	4	4	4	4	10
Financial autonomy	15	15	15	15	15
Sensibility to government subsidies	8	7	7	8	10
Transferability	1	1	1	1	20
Efficiency of the productive process	14	19	7	12	25
Total score	59	64	45	56	100

FL family labour

Table 5 Cost of production for milk and beef (US$/L or US$/kg live weight

	Rainy season		Dry season	
	Excluding FL	Including FL	Excluding FL	Including FL
Sale price of milk ($/L)	0.41	0.41	0.40	0.40
Total cost of production for milk ($/L)	0.31	0.40	0.36	0.51
Net profit for milk ($/L)	0.11	0.02	0.04	−0.11
Sale price of beef ($/kg live weight)	1.51	1.51	1.54	1.54
Total cost of production for beef ($/kg live weight)	0.93	1.34	1.33	1.92
Net profit for beef ($/kg live weight)	0.58	0.17	0.22	−0.37

Selling prices are for 2012–2013

US$ United State dollar, *FL* family labour

Fadul-Pacheco et al. (2013) for small-scale dairy farms, in a temperate subhumid area, reported lower scores from those found in the work herein reported for the agroecological scale. Farms analysed by Fadul-Pacheco et al. (2013) had lower scores on diversity and organization of space components. On the contrary, farms relied more on external inputs. Thus, it can be said that dual-purpose cattle farms have a higher sustainability in terms of the agroecological scale than the small-scale dairy farms reported by authors mentioned above.

In terms of the socio-territorial scale, the studied dual-purpose cattle farms do generate paid employment opportunities as well as one full-time not waged position for family labour, which contributes to the social and cultural development of the study area as has been put forward by McDermott et al. (2010). Family labour does represent a comparative advantage for this system, coinciding with reports of Posadas-Domínguez et al. (2014) and from work with peri-urban small-scale dairy farms in temperate areas. At the same time, family involvement in the farm ensures the transferability between generations.

The economic scale registered the lowest score of the three scales, with an average of 60/100 points, which determines that the dual-purpose farms studied have a medium sustainability. Nonetheless, the reported score for the economic scale is higher than reports by Fadul-Pacheco et al. (2013), applying the IDEA method in the assessment of sustainability of small-scale dairy farms in a temperate highland area under confinement, due to a large reliance on external inputs like concentrates and a higher intensity in the use of labour. The lower score in the economic scale in those systems is explained by factors related to management practices (dependency on external inputs like concentrates), and the low or nil value added to the milk produced, the main product.

The dry season is doubly hard for farmers. Firstly, the need for supplements significantly increases the costs of production of milk and beef. Secondly, the reductions in milk demand of up to 60 % in the production of cheese—that is because the traditional cheese produced in the region is only made during the rainy season, when aspects as cow feeds based 100 % on grazing as well as other aspects like environmental humidity and temperatures are factors that enable the traditional maturation of this cheese. On the contrary, it is during the dry season that demand for milk drops up to 60 %, at a time when feeding relies heavily on supplements which together with environmental aspects like high temperature and low humidity modify the physical-chemical characteristics of the milk (Hernández-Morales et al. 2011). These factors do not enable a good maturation of traditional cheese during the dry season, so that cheese making is limited to fresh cheeses that have a lower demand as well as a lower selling price (Rebollar et al. 2011).

Although dual-purpose farms base the feeding of their herds on grazing, it is notable that farmers invest as little as they can on improved pastures or in increasing the area under pasture that could enable them to have forage reserves for the dry season, contrary to findings of Espinosa-García et al. (2004) on the Gulf coast.

On the socio-territorial scale, dependence on commercial concentrates scored 10 out of 10 points, which means that farms imported less than 10 % of their feed needs (commercial concentrates). This gives them autonomy, which is one of the main principles of sustainable agriculture (Vilain et al. 2008). However, despite the overall autonomy of farms regarding commercial concentrates, they do have an effect. Commercial concentrates are expensive, having a negative impact on the economic viability of the farm, particularly during the dry season.

These results of weakness in the economic scale lead to an area of opportunity where applied research may provide options to improve, mainly in devising through participatory on-farm research with farmers' different forage management and feeding strategies.

We propose conserved forage stocks as hay or silage that may reduce the need for bought-in feeds and concentrates for the dry season, reducing milk and beef production costs. A decrease in feeding costs will greatly improve the cost/benefit ratios, the income of farmers and the economic viability of their farms.

Transferability of farms in the economic scale had a very low score (1 out of 20) due mainly to two factors. Land is expensive and the large mean farm surface makes them expensive for purchase, which put at risk the continuity of farms in the future.

Quality of milk had a low score, but not because the quality of milk was not appropriate. The reason was that the IDEA method privileges organic-certified products or protected designation of origin (PDO), obtaining 7 out of 10 points in this study. Contrary to what happens in Europe, there are only around 10 products with PDO in Mexico. This situation explains the low score in this indicator.

Conclusion

The study of dual-purpose cattle farms obtained high sustainability scores in the agroecological and socio-territorial scales; however, the economic scale had the lowest scores among the three scales, becoming the limiting factor, upon which it can be concluded that dual-purpose farms had a moderate overall sustainability.

Acknowledgments The authors express their gratitude to the farmers and their families participating in this work for their willingness and kindness in being part of the project. Their collaboration was fundamental in achieving the objectives. This work was undertaken thanks to the funding by the Mexican National Council for Science and Technology (*Consejo Nacional de Ciencia y Tecnología*—CONACYT) through grant 129449 CB-2009 and to the funding by Universidad Autónoma del Estado de México through the grants UAEM 3293/2012M and 1003/2012 RCA. Thanks also to CONACYT for the grant that enabled Isela Guadalupe Salas-Reyes to undertake her postgraduate studies. We are also grateful to the staff at CU UAEM Temascaltepec for their support and collaboration in the laboratory work and to all members of the research team on dual-purpose systems.

Conflict of interest The authors declare that they have no competing interests.

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