

Multicriteria Appraisal of the Potential of Converting Cattle Raising to Organic Production in the Humid Tropics of Chiapas, Mexico

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Abstract: This study characterizes technical and economic aspects of conventional dual-purpose (milk and meat) cattle raising in the humid tropics of Chiapas, Mexico and evaluates the potential for converting these farms to organic-or clean-production. An organic livestock raising conversion index with 10 indicators and 37 variables was used. Data was obtained through direct observation and a questionnaire applied to 50 farmers. Through a Cluster analysis (C), we classified Livestock Production Units (LPU) into three groups ($p < 0.05$). The highest values ($p < 0.05$) for the technical-economic indicators as well as ICOGAN were found for the LPU of C3, followed by those of C2 and finally, C1. All LPU evaluated scored very low for the indicators “veterinary prevention and care” and “ecological farm management”. The LPU of all three C scored high for the indicators “breeds and reproduction” and “soil fertilization”. In order for the LPU to increase their levels of sustainability and be certified organic, there is a need to strengthen farmer’s abilities in techniques of ecological production and management through technical advisory and assistance as well as permanent financial support. Furthermore, there is a need for all social actors involved to have a sense of co-responsibility for and be committed to the organic conversion process as well as a need for significant changes in state and federal cattle raising policies.

Key words: Organic conversion, indicators, ecological agriculture, sustainability, assistance, social

INTRODUCTION

As people’s health depends on the quality and safety of the food they consume, UNICEF (2016) indicates that food for the human population should be safe have high organoleptic-sensory quality and be nutritious, regardless of the type or scale of the agrifood system from which it originates. In many parts of the world, the population increasingly demands that their food be highly nutritious and harmless to their health and that it be environmentally friendly. However, food’s safety, nutritional level and organoleptic-sensory quality depends on its management throughout the production chain. Therefore, foods vary with respect to these three aspects of their quality as they originate from different types of agricultural and food processing systems.

From the Neolithic period almost until the mid-XX century, agriculture was natural (without agrochemicals) and food was healthy and nutritious (Reganold and

Wachter, 2016). Following the Second World War, the dominant type of agriculture which became known as the “Green Revolution” model was developed based on genetic improvement as well as intensive natural resource use, agrochemicals (fertilizers, fungicides, insecticides and herbicides); allopathic medicines (antibiotics, hormones and anti-parasitic medicines); irrigation, transportation and refrigeration systems; farm equipment dependent on fossil fuel and biotechnology.

While this type of agriculture substantially increased short-term production of food crops and livestock, it gradually became clear that the dominant food system was unsustainable due to unforeseen direct and indirect consequences including depletion of soil fertility, soil and water contamination, severe and even chronic intoxication due to agrochemical use, loss of agrobiodiversity, increased socioeconomic inequality and reduction in mid and long-term production levels (IFOAM., 2009; Reganold and Wachter, 2016).

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This critical situation led to development of certified organic and otherwise ecological agriculture with many similarities to that practiced centuries ago as well as to different forms of traditional agriculture still practiced in many places today. Cultivation of organic and ecological food concurs with many principles of clean production which aim to prevent risks to consumer health and the environment and also contributes to food security as mentioned, for example, in the 1978 Alma-Ata Declaration of the International Conference on Primary Healthcare. Such prevention of health and environmental risks is due to the fact that organic food is produced according to principles of health, agroecology, equity, precaution, responsibility and sustainability promotes human health and life on Earth given that it allows for naturally conserving integrated soil-plant-animal cycles, the environment and biodiversity; favors animal well-being; avoids use of agrochemicals and conserves energy) provides consumers with safe, nutritious food with high organoleptic quality and) is produced in agroecological systems which are energetically more efficient and produce fewer greenhouse gas emissions than food produced with high levels of external inputs and may even reduce greenhouse gases produced by other sources (IFOAM., 2009; Gerber *et al.*, 2009).

Certified organic agriculture is beginning to be introduced in many nations, particularly in the Global South due to the fact that producing safe nutritious food has become key to marketing products. For this reason, governments, Non-Governmental Organizations (NGOs), agribusiness and individual farmers of so-called “developed nations” as well as those of the global South are interested in evaluating their agricultural technologies and processes as well as the quality of their farm products in order to identify limitations to the quality of their food products and implement corrective measures to be able to compete in local, national and international markets (Reganold and Wachter, 2016).

Currently, 43.7 million hectares worldwide are used for certified organic agriculture (Lernoud and Schlatter, 2016). The continent with the most land devoted to organic agriculture is Oceania (17.3 million ha), followed by Europe (11.6 million ha), Latin America (6.8 million ha), Asia (3.6 million ha), North America (3.1 million ha) and Africa (1.3 million ha) (Lernoud and Schlatter, 2016). Mexico which takes third place worldwide with respect to number of organic farmers (169, 703) who devote a majority of their cropland to coffee has 501, 364 ha (2.3% of its agricultural surface area) under organic production (Lernoud and Schlatter, 2016).

In order to assure consumers and certifying organizations that agricultural products are organic, there is a need for clear, precise, concise indicators to evaluate whether food production is based on the principles of organic agriculture (Lernoud and Schlatter, 2016).

Existing studies report indicators for evaluating agricultural sustainability (Kouba, 2003; Coffey *et al.*, 2010; Peacock and Sherman, 2010), animal well-being (Napolitano *et al.*, 2009; Phythian *et al.*, 2011) and environmental effects on milk quality on organic farms (De Boer, 2003; Nauta *et al.*, 2006; Rozzi *et al.*, 2007; Muller-Lindenlauf *et al.*, 2010) or rate technical and economic performance of livestock production units (Escribano, 2016) or farmer attitudes toward converting their conventional farm to organic production (Midmore *et al.*, 2001) or even criticize organic livestock raising on the basis that animals may be undernourished and infested with parasites due to restrictions in use of anthelmintics (Vaarst *et al.*, 2005). However, literature referring to use of indicators to evaluate the feasibility of transition from conventional to organic farming is scarce (Bellon and Lamine, 2009) for some such existing studies, (Olivares *et al.*, 2005, Mena *et al.*, 2012).

Studies using indicators to evaluate the possibility of transitioning conventional farms to organic production allow for orienting further research as well as policies and other mechanisms for organic conversion as well as identifying limitations, potential and opportunities of existing farm systems, so that, government agencies and NGOs with the support of researchers may design strategies for transitioning toward organic production (Scoones 1998; Escribano, 2016). Functional limitations to organic farming those which are a result of conventional agricultural practices may be overcome by substituting one factor of production with another, for example, chemical fertilizer with organic fertilizer or chemical pest control with biological forms of control. Structural limitations on the other hand are a result of the larger economic and political context that prevents development of organic agriculture and are difficult to modify. Rather, their transformation requires multiple changes to the sociopolitical structure (Long and Villareal, 1992). The present study principally identifies functional limitations to converting conventional livestock raising to organic production.

Organic certification of animal products improves market options by allowing farmers to compete in agrifood markets (Nahed-Toral *et al.*, 2013; Reganold and Wachter, 2016), market their products in specialized niches and raise product prices. In order to identify comparative advantages of organic farm technologies and practices and the quality of resulting animal products, there is a need to develop methodologies to evaluate these technologies and products (Mena *et al.*, 2012; Escribano, 2016).

Many regions of Mexico including some parts of the state of Chiapas are suitable for converting conventional farms to organic production given that they already use few external inputs (Nahed-Toral *et al.*, 2010). Nevertheless, currently almost all of Mexico's

farm products are marketed as conventional. In 2016, Mexico produced 1.88 million tons of carcass meat with the state of Chiapas ranking third, producing 6.1% of the nation's meat. Meanwhile, in 2017, 11,607,493 L of milk was produced in Mexico 423,965 L of this in Chiapas. In the municipality of Tecpatan, Chiapas in 2016, 2,646.78 tons of carcass meat and 40,410.35 L of milk were reportedly produced and several studies considered livestock systems in this municipality to have a high potential for transitioning from conventional to organic production (Nahed-Toral *et al.*, 2010, 2013). Currently, Chiapas ranks first nation-wide in surface area of organic food production, largely due to its large surface area planted in organic coffee.

In Southeastern Mexico, conventional dual purpose cattle raising generally, involves low levels of external inputs (Nahed-Toral *et al.*, 2010), along with extensive grazing with varying levels of tree cover and histories of use crop associations of basic grains (principally maize and beans): rotation of land use (for example, among forest, pasture, crops and fallows) and use of trees and shrubs for fodder (Nahed-Toral *et al.*, 2012). Farms generally have low levels of technology and capital investment according to the following indicators) use of family labor, farm infrastructure use of manual tools, basic services (such as roads, electricity, water and communications) and training and advisory. Furthermore, farmers lack direct outlets to sell their products to food processors and marketers (Nahed-Toral *et al.*, 2012). There is a need to identify limitations, potential and opportunities of these traditional agrosilvopastoral systems with the objective of facilitating their transition toward organic certification and sustainability. With this in mind, the objective of the present study was to evaluate the potential for conversion of conventional dual purpose Livestock Production Units (LPU) to the organic production model in the municipality of Tecpatan, Chiapas.

MATERIALS AND METHODS

Location and characterization of the study area: The municipality of Tecpatan (including the recently formed municipality of Mezcalapa) is located in the Zoque ethnic region, in the humid tropics of the Northeastern region of the Mexican State of Chiapas, between 93°15' and 93°52' West longitude and 16°59' and 17°23' North latitude. Tecpatan is located in the mid-watershed of the Grijalva River within the Mesoamerican Biological Corridor. Altitude ranges from 80-1,100 MASL with an average of 320 MASL and most of the municipality's topography is rugged. About 65% of its soil is luvisol and lesser proportions are cambisol (8.3%), phaeozem (3.9%), plintisol (3.48%) and leptosol (0.61%); the remaining

surface area consists of bodies of water. Soil pH ranges from 5.13-6.45. According to the Koppen classification modified by Garcia, climate is warm-humid with abundant Summer rain (Af (m) w'' (i ') g). Most precipitation falls from June to November and the hottest months are April to June. In the municipal seat of Tecpatan, average annual temperature is 25°C and average annual precipitation 1,932 mm. Tecpatan has an extensive hydrographic network; the longest waterway is the Grijalva (or Mezcalapa) river which drains into the reservoir of the Netzahualcoyotl dam. In 2018, the municipality's population was reported to be 41,045 (20,420 male and 20,625 female), living in 359 towns and villages. Aside from monolingual Spanish speakers, the population includes 6,572 indigenous bilingual (Spanish and Zoque) speakers as well as 610 monolingual (Zoque) speakers. According to INEGI, Tecpatan had 4,495 agricultural and/or forestry production units in a total surface area of 67,619.18 ha, 2,628 of which raised cattle (study universe). These LPU have an average of 25 head of cattle and farm families raise a variety of crops and animals for self-consumption as well as for sale.

Estimation of sample size: Of the 2,628 LPU in the study area, a sample size was estimated using the following simple random sampling equation:

$$n_0 = \frac{z^2 pq}{d^2}$$

Where:

n_0 = Sample size

z^2 = Risk set at 1.96

p = Estimated proportion of livestock raising population in the region (85%)

q = 1-p

d = Maximum error permitted (10%)

A value of 50 LPU was obtained for analysis. In order to select these LPU, we carried out an intentional search of segments (LPU) that represent the typology of the farms, beginning with those whose owners had participated in other projects with researchers of the present study (Nahed *et al.*, 2018). In order to reach a sample size of 50 LPU, after selecting several farmers who agreed to participate in the study, we asked them to propose other farmers with different types of management in order to be able to contrast those LPU with practices more closely following the organic standards with those involving practices prohibited by organic standards. This allowed for differentiating several groups of LPU through a cluster analysis for later comparison.

Table 1: Technical-economic indicators used to characterize Livestock Production Units (LPU) in the humid tropics of Chiapas, Mexico

| Technical-economic indicators | Definitions |
|---|---|
| Age of LPU owner (years) | Age of LPU owner |
| Herds size (AU) | According to the equation proposed by Scarnecchia and Kothmann (1982), Animal Units (AU) of each LPU were standardized according to live weight, age and physiological stage (calf, cow, steer, bull) AU raised per hectare of land* |
| Animal load (AU/ha) | AU raised per hectare of land* |
| Own grassland surface area (ha) | Surface area for grazing that is owned by the farmer |
| Rented grassland surface area (ha) | Surface area for grazing that is rented |
| Total supplement (kg/cow/year) | Kg of feed supplement (all feed other than fodder) produced in the LPU plus supplement purchased from outside the LPU per cow per year |
| Birth rate (%) | Percentage of young born annually with respect to total number of females fit for reproduction in the LPU* |
| Adult death rate (%) | Annual percentage of death of adult cattle (due to illness or accident) with respect to total number of adults in the LPU* |
| Death rate of young (%) | Annual percentage of death of young (during lactation) with respect to total number of young born in the LPU |
| Milking (months) | Number of months cows are milked |
| Milk production (L/day) | Average liters of milk produced per cow per day |
| Milk production (L/year) | Average liters of milk produced per cow per year |
| Annual cattle feed cost (%) | LPU's annual percentage of cost in cattle feed with respect to income from sale of meat and milk |
| Cost of production per kg LW (Mexican pesos/kg) | Fixed and variable costs of producing 1 kg of Live Weight (LW) |
| Cost of production of milk (Mexican pesos**/L) | Fixed and variable costs of producing 1 L of milk |
| Cost of production per cow (Mexican pesos**/year) | Fixed and variable costs of maintaining a cow in production over 1 year |
| Gross margin per cow (Mexican pesos**/year) | Gross income that the average cow provides to the LPU per year |
| Total net margin per cow (Mexican pesos**/year) | Difference between gross margin and fixed and variable costs, divided by average annual number of cows in the LPU over 1 year; fixed costs include family and hired labor |
| Economic efficiency | Efficiency with which the farmer uses income from sales and subsidies to satisfy the LPU's needs (fixed and variable costs) |
| Dependence on petroleum (%) | Percentage of annual spending for petroleum-based inputs (chemical fertilizers, plastics, non-renewable energy, etc.) |
| Feed autonomy (%) | Percentage of spending for purchased feed with respect to total feed expense which consists of feed purchase+grass cultivation and improvement+renting of grazing land |

Procedure for obtaining information: Information used to calculate the organic livestock raising conversion index (ICOGAN according to its Spanish initials) was obtained through direct observation as well as a questionnaire applied to the owners of the 50 LPU. The farms of those interviewed are located in the municipal seat of Tecpatan (10) and in the villages of Luis Espinoza (21), Emiliano Zapata (8), El Porvenir (5), Cushaygen (2) and Raudales Malpaso (4).

Characterization of livestock production units: Technical-economic characterization of cattle raising was carried out using quantitative indicators previously defined in other studies (Mena *et al.*, 2012; Delgado-Pertinez *et al.*, 2013). These indicators are presented in Table 1.

Evaluation of the potential for converting conventional livestock production units to organic production: The level of organic production of each LPU was evaluated by applying ICOGAN, proposed by Mena-Guerrero *et al.* (2009) and adapted to the context of Mexican agriculture by Nahed-Tarol *et al.* (2012). ICOGAN which was developed by consulting twelve researchers in organic livestock raising as well as organic regulations (Mena-Guerrero *et al.*, 2009), consists of 37 variables conforming 10 indicators (Table 2). In order to select variables and indicators, those consulted took into account the following ecological agriculture principles adequate use of permitted, prohibited and restricted substances for

preventing, curing and eradicating pests and diseases and efficient use of agroecological technologies that require little capital and allow for optimal use of local resources as well as long-term maintenance of the physical environment, biological diversity and soil productive capacity (Mena-Guerrero *et al.*, 2009; Nahed-Toral *et al.*, 2012).

Table indicators, weighting factors and variables that integrate the organic livestock raising conversion index (ICOGAN) applied to traditional dual purpose cattle farms in the humid tropics of Chiapas, Mexico.

Feeding management (0.12):

- Feeding of animals only with feed permitted by organic regulations
- Grazing of animals
- At least 60% of Dry Matter (DM) of daily ration is fibrous fodder
- At least 50% of feed comes from the same or another ecological farm.

Sustainable grassland management (0.15):

- Rotation of pastures
- Appropriate animal load
- Association of fodder crops
- Cultivation of woody fodder crops
- Silvopastoral system

Table 2: Average value for ICOGAN, range of values (minimum and maximum) of ICOGAN and classification of potential of organic conversion by clusters of livestock production units in the humid tropics of Chiapas, Mexico

| Variables | Clusters | | | F-values | p-values |
|--------------------|---------------------------------|---------------------------------|---------------------------------|----------|----------|
| | 1 | 2 | 3 | | |
| n | 17 | 14 | 19 | - | |
| Range (%) ICOGAN | 20.3-48.8 | 50.3-54.8 | 56.6-77.7 | - | |
| Average (%) ICOGAN | 42.6 (± 7.4) ^a | 49.9 (± 2.2) ^b | 61.5 (± 5.5) ^c | 42.8 | 0.0001 |

^{a,b,c}Different letters in the same row indicate significant differences ($p < 0.05$); * F test: alpha of 95 %; ICOGAN: organic livestock raising conversion index

Soil fertilization (0.06):

- Organic
- Chemical

Weed control in grasses and crops (0.06):

- Mechanical
- Chemical

Pest control in grasses and crops (0.06):

- Ecological
- Chemical

Veterinary prevention and care (0.12):

- Application of obligatory vaccines
- Quarantine of introduced and sick animals
- Natural treatment of illnesses
- Use of natural internal anti-parasite medicines
- Use of permitted allopathic internal anti-parasite medicines (maximum twice yearly)
- Use of natural external anti-parasite medicines

Breeds and reproduction (0.06):

- Farm has only cross-breed animals and/or those adapted to the region
- Animal reproduction is through natural mounting

Animal well-being (0.07):

- Natural lactation until 8 months of age
- Sufficient space per animal in rooved enclosures and outdoors
- Sufficient feeders and water sources
- Protection of animals from inclement weather (cold, heat, rain and humidity)
- Horns of young animals are cut and those of older animals are trimmed.

Food safety (0.15):

- Strict hygienic-sanitary control of facilities, equipment and milking and milk management

- Animals are free of brucellosis and tuberculosis
- Animals seropositive to brucellosis and tuberculosis are eliminated
- Animal products are free of antibiotics, hormones and pesticides

Ecological farm management (0.15):

- Farmer receives training and/or advisory for organic certification
- Farmer has organic transition plan or is certified
- Farmer keeps records of the organic transition process
- Farmer receives incentives for organic production
- Farmer receives a fair constant price for sale of products year round

Variables and calculation of indicator values: The 37 variables that integrate the 10 indicators of ICOGAN (Table 3) were coded as binomial (0, 1) in order to homogenize the original units of measure and due to the fact that organic regulations are based on specific criteria regarding use of permitted (1) and prohibited (0) inputs and practices. In this manner, each variable acquires a value of its own which is mutually exclusive with the others and has a binomial or Bernoulli distribution (Zar, 1984) which facilitated calculation of the value of each variable. The total value for each indicator is the arithmetic average of the values (0 or 1 responses) of its variables (Grimm and Wozniak, 1990). In this manner, the values of the ten indicators were standardized to a relative percentage scale. The optimal value (100%) of an unweighted indicator is achieved when the responses of all its variables are positive (coded as 1). A percentage value of each indicator in the LPU was calculated by summing the responses of their variables (0 or 1) and multiplying this number by 100. This index is based on the multi-criteria approach regarding weighting and aggregation of information (Munda *et al.*, 1994; Falconi and Burbano, 2004; Munda, 2004) and is intended to facilitate understanding of technological and environmental limitations and potential of LPU in a specific economic and social context which facilitates farmer decision making, so that, the farm may transition toward organic certification.

Table 3: Technical-economic indicators of the livestock production units by clusters in the humid tropics of Chiapas, Mexico

| Technical-economic indicators | Clusters | | | F, p-values |
|---|--------------------------------|----------------------------------|-------------------------------|--------------|
| | 1 | 2 | 3 | |
| N = 50 | 17 | 14 | 19 | - |
| Age of LPU owner (years) | 58 (±12) | 51 (±13) | 56 (±19) | NS |
| Herds size (AU) | 65.9 (±63.1) ^a | 51.5 (±25.2) ^{a,b} | 34.9 (±18.3) ^b | 4.46, 0.017 |
| Animal load (AU/ha) | 1.57 (±1.1) ^a | 1.21 (±.4) ^{a,b} | 1 (±.4) ^b | 4.42, 0.017 |
| Own grassland surface area (ha) | 29.9 (±19.9) | 33.9 (±19.1) | 34.5 (±19.7) | NS |
| Rented grassland surface area (ha) | 18.2 (±29.2) | 5.6 (±7.8) | 3.6 (±8.8) | NS |
| Total supplement (kg/cow/year) | 1367.9 (±2471.8) ^a | 1064.4 (±1288.5) ^a | 209.9 (±428.6) ^b | 3.23, 0.48 |
| Birthrate (%) | 81 (±36) | 90 (±35) | 85 (±33) | NS |
| Adult death rate (%) | 2.9 (±2.9) | 2.6 (±3.1) | 2.5 (±6.3) | NS |
| Death rate of young (%) | 13.6 (±9.4) | 9.1 (±7.3) | 9.5 (±12.6) | NS |
| Milking (months) | 8.0 (±1.4) | 7.9 (±1.0) | 8.2 (±1.7) | NS |
| Milk production (L/day) | 6.0 (±2.7) | 5.0 (±2.1) | 4.5 (±2.3) | NS |
| Milk production (L/year) | 794.9 (±589.0) | 742.0 (±310.6) | 666.8 (±410.9) | NS |
| Annual cattle feed cost (%) | 34.1 (±43.5) ^a | 17.9 (±17.7) ^{ab} | 6.1 (± 9.1) ^b | 4.92, 0.011 |
| Cost of production per kg LW (Mexican pesos/kg) | 69.19 (±39.9) ^a | 49.8 (±11.8) ^{a,b} | 37.2 (±18.1) ^b | 6.55, 0.003 |
| Cost of production of milk (Mexican pesos**/L) | 12.0 (±3.1) ^a | 12.4 (±3.9) ^b | 8.9 (±2.9) ^b | 5.79, 0.006 |
| Cost of production per cow (Mexican pesos**/year) | 13891.7 (±7704.5) ^a | 11684.0 (±4624.2) ^{a,b} | 8476.1 (±5140.6) ^b | 3.38, 0.032 |
| Gross margin per cow (Mexican pesos**/year) | 15345.7 (±70001.3) | 14373.1 (±4396.8) | 15949.7 (±8186.4) | NS |
| Total net margin per cow (Mexican pesos**/year) | 1454.0 (±39.24.6) ^a | 2689.1 (±3580.4) ^a | 7473.6 (±5248.2) ^b | 9.38; 0.000 |
| Economic efficiency | 1.2 (±.4) ^a | 1.3 (±.4) ^a | 2.0 (±.7) ^b | 11.07, 0.000 |
| Dependence on petroleum (%) | 8.4 (±6.1) ^{ab} | 13.7 (±8.3) ^b | 4.6 (±4.9) ^a | 7.56, 0.001 |
| Feed autonomy (%) | 22.6 (±34.0) | 18.1 (±31.9) | 38.3 (±42.9) | NS |

^{a, b, c}Different letters in the same row indicate significant differences (p<0.05); NS: Non-significant; F-test: alpha of 95 %; AU: Animal unit; * Data refers to AU in the LPU when the questionnaire was applied; **Exchange rate of Mexican pesos to US dollars as of March 05, 2019 was 19.97

Weighting of indicators: The coefficient for weighting each indicator (Table 3) was based on the importance of each indicator to the principles of agroecology and organic livestock raising and the difficulty of eliminating or substituting use of inputs or practices prohibited by organic regulations. The weighted value of each indicator was obtained by multiplying the arithmetic average of the values of its variables by its specific weighting factor. A sensitivity analysis of weighting coefficients for each predetermined indicator of ICOGAN influenced the results; the influence of the coefficient depends on the responses obtained for the variables that integrate each of the indicators. Furthermore, in order to facilitate interpretation and discussion of results, we classified the values of the indicators, their variables and ICOGAN as a whole into five categories of potential for organic conversion; very low (0-20%), low (21-40%) intermediate (41-60%), high (61-80%) and very high (81-100%).

Systematization and analysis of information: Data obtained from the 50 LPU sampled was systematized in two Excel databases-one for the technical-economic indicators and the other for ICOGAN. First, a hierarchical cluster Classification (C) was carried out with the furthest neighbor method where the grouping factor was the series of data of the weighted ICOGAN of the 50 LPU. This classification allowed for analyzing by groups each technical-economic indicator, the ten indicators making up ICOGAN and ICOGAN as a whole. Secondly, a Kolmogorov-Smirnov normality test was applied to the

indicators (Grimm and Wozniak, 1990). Results indicated that data should be transformed to approach the normal distribution through its natural logarithm or arcsine (according to the nature of the data) in order to be able to carry out a comparison of the means through Analysis of Variance (ANOVA). The results of the indicators whose average values differed significantly among groups in the ANOVA test were submitted to a posteriori contrasts (multiple comparisons) through Tukey's HSD or the Games-Howell method (depending on the homogeneity of variances test). All statistical analyses were carried out using Version 15 of the SPSS statistical package (Mehta and Patel, 2011).

RESULTS AND DISCUSSION

Cluster analysis: A cluster analysis allowed for identifying three clearly differentiated groups of LPU (p<0.05) with different values for ICOGAN (Fig. 1). We attempted to achieve an equal number of repetitions (or LPU) in each cluster (p<0.05). The LPU of C1 had the lowest values-indicating low potential for organic conversion and those of C3 had the highest-indicating high potential (Table 4). This grouping allowed for planning agroecological technologies for each group of farmers which may help them overcome their limitations. In another study by Nahed-Toral *et al.* (2013), organic certification of milk and of animals sold live for meat has been achieved after overcoming limitations identified through ICOGAN. The objective of ICOGAN is for

Table 4: Indicators and values of ICOGAN of livestock production units grouped by clusters in the humid tropics of Chiapas, Mexico

| ICOGAN /Indicators | Clusters | | | F, p-values |
|-----------------------------------|---------------------------|----------------------------|---------------------------|-------------|
| | 1 | 2 | 3 | |
| Feeding management | 67.5 (±31.6) ^a | 80.4 (±10.6) ^{ab} | 96.1 (± 9.4) ^b | 9.0, 0.000 |
| Sustainable grassland management | 36.5 (±12.2) ^a | 47.1 (±9.9) ^b | 53.7 (±13.4) ^b | 9.0, 0.000 |
| Soil fertilization | 88.2 (±33.2) | 92.8 (±26.7) | 100.0 (±0.0) | NS |
| Weed control in grasses and crops | 47.1 (±51.4) ^a | 71.4 (±46.9) ^{ab} | 94.7 (±22.9) ^b | 5.9, 0.005 |
| Pest control in grasses and crops | 64.7 (±49.2) | 85.7 (±36.3) | 94.7 (±22.9) | NS |
| Veterinary prevention and care | 27.3 (±14.2) ^a | 36.7 (±11.7) ^a | 49.8 (±18.0) ^b | 9.9, 0.000 |
| Breeds and reproduction | 97.1 (±12.1) | 96.4 (±13.4) | 100 | NS |
| Animal well-being | 67.1 (±9.8) | 65.7 (±9.4) | 68.4 (±15.4) | NS |
| Food safety | 40.4 (±21.8) ^a | 57.4 (±15.9) ^b | 66.7 (±17.1) ^b | 9.1, 0.000 |
| Ecological farm management | 8.2 (±10.1) ^a | 5.7 (±9.4) ^a | 22.1 (±14.1) ^b | 6.3, 0.004 |
| ICOGAN | 42.6 (± 7.4) ^a | 49.9 (±2.2) ^b | 61.5 (±5.5) ^c | 51.8, 0.000 |

^{a,b,c} Different letters in the same row indicate significant differences (p<0.05); NS: Non-significant; *F-test: alpha of 95 %; ICOGAN: Organic livestock raising conversion index

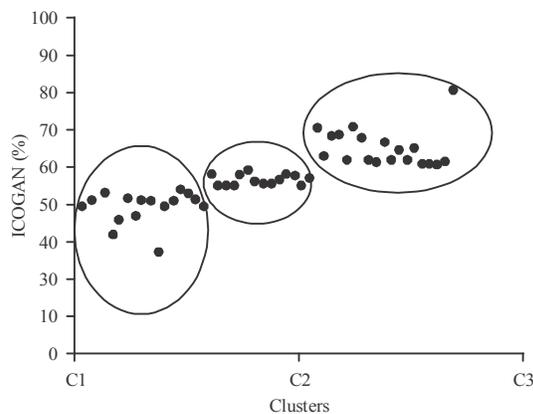


Fig. 1: Clusters (C) of the organic livestock raising conversion index (ICOGAN) of livestock production units in the humid tropics of Chiapas, Mexico

conventional LPU to be capable of sustaining themselves over time, and to modify themselves when conditions demand. For ecological and social resources and processes involved in LPU to be capable of continuing to function, they must be capable of self-regulation, coordination, reorganization and adapting themselves in the face of internal and external changes (Nahed *et al.*, 2006).

Context of cattle raising in the study area:

In the study area, the predominant agrosilvopastoral dual purpose cattle raising system has produced milk and weaned calves for sale for five decades (Nahed-Toral *et al.*, 2012). This system follows traditional practices with few external inputs, uses a wide variety of types of vegetation in an integrated manner and follows a management calendar adapted to seasonal variability. Cattle raising is integrated with crop production and forestry through energy flows and circulation of materials by fertilizing crops with manure, feeding cattle with agricultural waste and grazing them in areas with a tree

gradient consisting of one or more of the following: treeless grassland; grassland with living fences, shrubs and/or fallows; dispersed trees and forested areas, used in an alternating manner over the course of the annual cycle.

In general, there is a tendency for the technical-economic indicators of C1 to have the lowest values and those of C3 to have the highest. Owners of the LPU evaluated have an average age of 55 which is a disadvantage for developing agrosilvopastoral systems and organic livestock raising in the region given that older adults show less openness to receiving training or advisory and are less interested in adopting technological innovations. Surface area of grassland owned by the farmers ranged from 29.9-34.5 ha while that of rented grassland ranged from 3.6-18.2 ha. All LPU have cattle of the breed Zebu *Bos indicus* and of a mixed-breed biotype, both of which are crossed with some European breeds (*Bos Taurus*) particularly Swiss and Holstein and to a lesser extent Simmental. In the majority of LPU (97%), cows are milked manually once daily, stimulating milk flow by allowing the calf to suckle 2-3 min before milking (Nahed-Toral *et al.*, 2012). This milking technique is commonly used in the Mexican tropics and has been previously described by Ortiz (1982).

In all LPU, the breeding bull is continually with the cows and therefore, siring occurs through natural direct mounting. For this reason, calves may be born any time of year. Weaning occurs naturally between 7 and 8 months of age at an average weight of 207.5 kg (±9.6). All calves are sold upon weaning to be fattened in other regions of Mexico, principally in central or Northern Mexico. Sale of milk, weaned calves and discarded cows to intermediaries is farmer’s principle source of income. Involvement of intermediaries in marketing as in other regions of the Mexican tropics and in other regions of the world seriously limits the sale price for live animals and animal products.

Herd size was greatest in C1 and smallest in C3 ($p < 0.05$). A similar tendency ($p < 0.05$) was observed for animal load and surface area of rented grassland ($p > 0.05$) and an inverse tendency ($p > 0.05$) for surface area of owned grassland. LPU (principally those of C1) rent grasslands during the dry season in order to prevent excessive trampling and overgrazing of the little land they have. Given insufficient surface area for grazing in LPU of C1, these farms have a greater animal load in their grasslands than do those of C2 and C3; nevertheless, all three C are within the limit of two AU per hectare stipulated by organic regulations (IFOAM., 2018).

One principle difference among the three C is feed supplementation: up to 6.5 times more mineral feed supplements such as salts are provided by C1 and C2 farmers at free access, mixed with energy supplements (for example, molasses, maize kernels and maize pericarp) and/or protein supplements (for example, chicken manure and feed concentrates) as compared to that provided by C3 farmers (209.9 kg per cow per year; $p < 0.05$) which is similar to that reported by Orantes-Zebadua *et al.* for the same study area (1-3 kg of supplement per cow per day).

A high birth rate is observed for all three C, varying from 81.0-90.0% which is greater than that reported by Nahed-Toral *et al.* (2013) for Mazapa, Chiapas (67%), Huitiupan, Chiapas (61%), Tacotalpa, Tabasco (72.4%) and Tecpatan, Chiapas (72.8%). The death rate for adult animals was low, varying from 2.5-2.9% which approximates values of 2.6-5.1% reported by Nahed-Toral *et al.* (2013) for the same area while the death rate for young animals was relatively high, varying from 9.1-13.6% for the three C (> 0.05) which is greater than rates reported by Nahed-Toral *et al.* (2013) 5.3-7.3%.

Number of months of milking per year, milk production per cow per day, and milk production per cow per year did not statistically differ among C. For the same study area, Orantes-Zebadua *et al.* report a daily milk production level per cow (4.4 ± 1.8 L) which is very similar to that of C3 (4.5 ± 2.3 L). Meanwhile, for the same study area, Nahed *et al.* (2018) report annual milk production values which are greater (1183 ± 4.3 L) than those estimated in the present study.

Farmer's annual feed cost with respect to income from sale of meat and milk was greatest ($p < 0.05$) in C1 and lowest in C3. Cost of production per kg of meat and per L of milk varied ($p < 0.05$) among C and production costs of both products were highest for C1 and lowest for C3. Similarly, cost of production per cow was greatest ($p < 0.05$) in C1 and lowest in C3. Gross margin per cow did not vary ($p > 0.05$) among C; nevertheless, net margin (income) per cow per year was greatest ($p < 0.05$) in C3 ($\$7473.6 \pm \5248.2).

Low levels of production of animals and animal products and high costs of production lead to LPU's net

margin of income—principally those of C1—being very low. Zepeda-Cancino *et al.* indicate that in the study area, lack of income aside from livestock raising as well as marketing problems such as low milk prices with respect to cost of production (which includes family labor) as well as sale of animals to intermediaries discourages farmers as they are barely able to satisfy their basic needs with the exception of those farmers that have another income source. Therefore, younger generations tend to lose interest in farming and continuity of LPU may be reduced.

Results of economic efficiency (considering subsidies and family labor) indicate that the LPU of C3 are more efficient ($p < 0.05$) than those of C2 and C1. For the indicators related to cost of production, especially, “dependence on petroleum” and “cost of production per cow”—C3 has notably lower costs, principally due to low purchase of external inputs and little use of machinery which leads to less contamination. Meanwhile, the level of feed autonomy was similar among LPU of all three C ($p > 0.05$), although, C3 had a somewhat greater level due to a lower percentage of total annual farm costs in purchase of feed ($p > 0.05$; Table 4).

Evaluation of viability of organic conversion of LPU:

Table 4 shows average percentages of approximation to the organic model for the ten indicators of ICOGAN and for ICOGAN as a whole for the LPU grouped by C. The values of all indicators for C3 are significantly greater ($p < 0.05$) or greater to a non-significant level ($p > 0.05$) than the values of C1 and C2. With the exception of the indicator “ecological farm management” which shows very low potential of organic conversion, the rest of C3's indicators show intermediate to very high potential of conversion. C2 has significantly greater values than C1 ($p < 0.05$) for the indicators “sustainable grassland management” and “food safety” while “feeding management”, “soil fertilization”, “weed control in grasses and crops”, “pest control in grasses and crops”, and “veterinary prevention and care” were greater to a non-significant level for C2 than for C1 ($p > 0.05$), although, the values of these seven indicators vary greatly, showing that the potential for organic conversion varies for different aspects of farm management. C1 has higher values at non-significant levels than C2 ($p > 0.05$) for the indicators “breed and reproduction”, “animal well-being” and “ecological farm management”. For these two clusters, these indicators vary greatly with respect to their potential for organic conversion. The five indicators that show high to very high potential for conversion for all three C are “feeding management”, “weed control in grasses and crops”, “pest control in grasses and crops”, “breed and reproduction” and “animal well-being”.

The values of ICOGAN as a whole are different for each of the three C ($p < 0.05$); C3 has the highest potential for organic conversion followed by C2 and finally, C1.

These results indicate that potential for organic conversion of the three C of the LPU evaluated ranges from low to intermediate-similar to that reported by Nahed-Toral *et al.* (2013) where after extensive training to overcome limitations of their LPU, farmers achieved organic certification which has allowed them to increase the demand for their products and consequently their prices and in general their LPU have become more sustainable.

Feeding management: The variables for the indicator “feeding management” show very high potential for organic conversion for C3 (84.2-100%) and for C2 (100%), except for the variable feeding of animals only with feed permitted by organic regulations which has low potential for C2 (21.4%). The variables of C1 show high to very high potential for organic conversion (70.6-94.1%) with the exception of feeding of animals only with feed permitted by organic regulations which has low potential (29.4%). The most significant strength regarding feeding in the LPU evaluated is that it is based on grazing and the factor which most limits the potential for organic conversion for some LPU is use of commercial feed, chicken manure and/or chemical feed additives these should be substituted by permitted feed and farms should assure that purchased grains and fodder come from other ecological farms.

Sustainable grassland management: For the indicator “sustainable grassland management”, the LPU of all three C have a very high potential for organic conversion (88.2-100%) for the variables pasture rotation and appropriate animal load. Meanwhile, in all three Cs, the variables association of fodder crops and silvopastoral systems show very low viability of conversion (C1 and C2 = 0.0% for both variables and C3 = 5.3 and 10.5% for the two variables) while the variable cultivation of woody fodder crops ranges from very low to intermediate (C1 = 5.9, C2 = 35.7 and C3 = 52.6%). In order to achieve sustainable grassland management, there is a need to improve the above-mentioned variables, associate leguminous species in any pastures in which grains are currently planted as monocultures and plant in different spatial arrangements local woody fodder crops such as *Erythrina* spp., *Gliricidia sepium* and *Leucaena leucocephala*. Such diversified pastures protect biodiversity and provide greater soil protection as well as environmental services such as carbon capture, reduction in CH₄ and N₂O emissions and mitigation of climate change (Jose, 2009).

Soil fertilization: For the indicator “soil fertilization”, all LPU of all three C show very high viability of conversion to the organic model (C1 = 88.2, C2 = 92.8

and C3 = 100%). These high values are due to the fact that use of chemical fertilizers in grasslands is minimal; rather, nutrients are contributed to the soil only by cattle depositing manure during grazing. However, in the majority of the LPU evaluated, manure accumulated by cattle in stables is not processed into organic fertilizer (for example, compost, bocashi, vermiculture, biofertilizers or biofermentation) and green manures or cover crops are not used to fertilize grasslands, as suggested by CERTIMEX (200) and IFOAM (2018).

Weed control in grasses and crops: For the indicator “weed control in grasses and crops”, the LPU of all three C have intermediate to very high viability of organic conversion (C1 = 47.0, C2 = 71.4 and C3 = 94.7%). This is due to the fact that the majority of farmers control weeds manually rather than using chemical herbicides. Rather than completely eradicating weeds, ecological weed control involves maintaining populations of spontaneously growing plant species in pastures and crops at levels by which interspecies competition does not reduce productivity of grasses.

Pest control in grasses and crops: With respect to the indicator “pest control in grasses and fodder crops”, the LPU of all three C have high to very high potential for organic conversion (C1 = 64.7, C2 = 85.7 and C3 = 94.7%). This is due to the fact that farmers do not use chemical pesticides to control insects in their grasslands. Rather, control is principally manual and to a lesser extent mechanical through grazing. Use of botanical insecticides and repellents (Cook *et al.*, 2007) as well as integrated pest management which includes ecological soil and biodiversity management (Von Borell and Sorensen, 2004) could improve efficiency of pest and disease control.

Veterinary prevention and care: With respect to the indicator “veterinary prevention and care”, the LPU of the three C have low to intermediate potential for organic conversion (Table 3). Values for the variables of this indicator range from very low to very high; application of obligatory vaccines such as brucellosis and paralytic rabies (C1 = 70.6, C2 = 92.9 and C3 = 100%); quarantine of introduced and sick animals (C1 = 52.9, C2 = 71.4) and C3 = 89.5%); natural treatment of illnesses (C1 = 0.0, C2 = 7.1 and C3 = 89.5%) use of natural internal anti-parasite medicines (C1 = 0.0, C2 = 0.0 and C3 = 10.5%) use of permitted allopathic internal anti-parasite medicines (C1 = 41.2, C2 = 42.8 and C3 = 78.9%) and use of natural external anti-parasite medicines (C1 = 0.0, C2 = 7.1 and C3 = 15.8%). Some farmers do not administer internal anti-parasite medicines, others administer more than the two permitted by organic

regulations per year and the majority sporadically use antibiotics following organic regulations to treat infections in their animals. Raising creole breeds and their crosses, adequate nutrition, preventative measures that favor resistance to climatic factors and diseases and substitution of antibiotics and anti-parasite medicines with natural methods such as homeopathy, herbalism and acupuncture would help to improve this indicator (Mena-Guerrero *et al.*, 2009).

Breeds and reproduction: The variables for the indicator “breeds and reproduction” show very high potential for organic conversion (92.8-100%), due to the fact that over 75% of bovines are cross-breeds that are adapted to the region. In the large majority of LPU of all three C, animals reproduce through direct mounting. Adaptation of the animals to local climatic conditions and traditional management techniques varies from low to high as reflected by the high values for the technical-economic indicator birth rate (C1 = 81.0, C2 = 90.0 and C3 = 85.0%) while the technical-economic indicator death rate of young is relatively high (C1 = 13.6, C2 = 9.2 and C3 = 9.6%), although, adult death rate is low (C1 = 2.9, C2 = 2.6 and C3 = 2.5%). Although, organic regulations permit artificial insemination, in the majority of the LPU mounting is direct and continuous as are oestrus of females and births which avoids use of chemical hormones. Farms would benefit by having breeding bulls of mixed breeds adapted to local conditions in order to develop resistance to diseases and parasites (Nauta *et al.*, 2006; Von Borell and Sorensen, 2004; Hersleth *et al.*, 2012).

Animal well-being: The indicator “animal well-being” shows very high potential for organic conversion (100%) for the variables natural lactation until 8 months of age and sufficient feeders and water sources. This is followed by horns of young animals are cut and those of older animals are trimmed which shows high to very high potential for conversion (C1 = 94, C2 = 85.7 and C3 = 73.7%), followed by sufficient space per animal in rooved enclosures and outdoors which shows low to intermediate viability (C1 = 23.5, C2 = 28.6 and C3 = 52.6%) and protection of animals from inclement weather (cold, heat, rain and humidity) which shows very low potential (C1 = 17.6, C2 = 14.3 and C3 = 15.8%). In general, for all three C the latter two variables should be improved to provide optimal conditions, so that, animals develop their functions of lactation, growth, reproduction and production and are able to comfortably satisfy their biological needs (Vasta *et al.*, 2012).

Food safety: The variables for the indicator “food safety” that show high to very high potential for organic conversion are animals are free of brucellosis and

tuberculosis (C1 = 67.6, C2 = 89.3 and C3 = 89.5%) and animals seropositive to brucellosis and tuberculosis are eliminated (C1 = 76.5, C2 = 100 and C3 = 100%). However, some animals still prove to be seropositive in local disease diagnosis and vaccination campaigns. Values for the variable animal products are free of antibiotics, hormones and pesticides range from very low to high (C1 = 17.6, C2 = 33.3 and C3 = 66.7%), indicating highly varying levels of potential for conversion. Few LPU have strict hygienic-sanitary control of facilities, equipment and milking and milk management and therefore, they have very low viability of conversion for this variable (C1 = 0.0, C2 = 7.1 and C3 = 10.5%). As evidence of “safety of animal products (milk, cheese and meat)” is the guarantee of quality that farmers offer to consumers, the low levels of this indicator provide an obstacle to fulfilling organic standards for all three C, although, principally for C1 and C2. Therefore, there is a need to implement strict hygienic-sanitary control of infrastructure and use management practices that avoid chemical substances such as hormones prohibited by organic standards as well as physical contaminants (pieces of metal and other garbage). Strict hygienic-sanitary control, together with organoleptic traits (flavor, aroma, color) and nutritional quality indicate sanitary and nutritional quality of food and promote consumer confidence (Escribano, 2016). Finally, pasture-based feeding has become important to consumers who consider meat from animals raised in such conditions to be more natural and less contaminated and that such practices show greater respect for animal well-being.

Ecological farm management: For the indicator “ecological farm management”, the only variable with intermediate to high potential for organic conversion is farmer receives training and/or advisory for organic certification. The other four variables indicate very low viability (0-22%). This is due to the fact that farmers have not been trained to improve their farms with respect to the five variables that determine this indicator. Therefore, they should receive training and advisory for transitioning to organic production. There is also a need to keep records of feeding, disease and treatment, production, processing and marketing (Escribano, 2016). Aside from farmer management, government agencies and NGOs should provide incentives for improving quality. The existence of fair, constant prices throughout the year for sale of products would motivate farmers to continue to improve their LPU though sustainable techniques (Hersleth *et al.*, 2012; Nahed-Toral *et al.*, 2012) while also allowing them to reproduce their traditional way of life. The greater net margin and the greater economic efficiency of LPU of C3 and C2 allow for greater economic reinvestment in the farms in order to carry out modifications which are necessary for achieving organic certification.

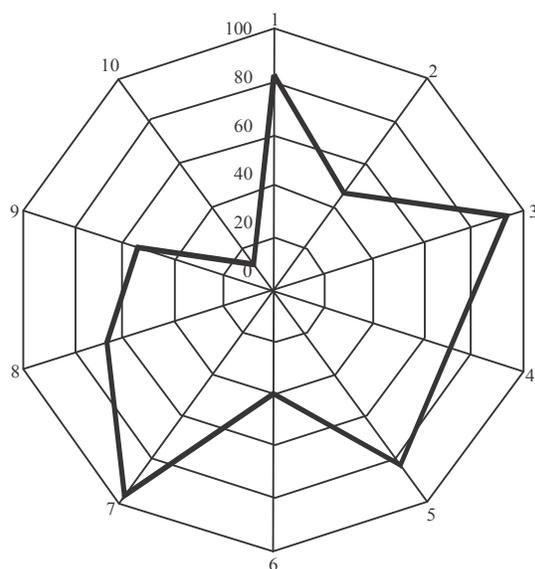


Fig. 2: Summary of indicators that limit and favor organic conversion, regardless of the cluster to which livestock raising units belong: (1) Feeding management, (2) Sustainable grassland management (3) Soil fertilization, (4) Weed control in grasses and crops, (5) Pest control in grasses and crops, (6) Veterinary prevention and care, (7) Breeds and reproduction, (8) Animal well-being, (9) Food safety (10) Ecological farm management

Limitations and potentials of organic conversion of conventional cattle raising: Evaluating the potential for conversion of conventional cattle raising to the organic production model provides an opportunity to identify limitations, potentials (Fig. 2) and opportunities for promoting sustainable livestock raising (Nahed-Toral *et al.*, 2012, 2013). Those ICOGAN indicators with limited potential for organic conversion of the LPU evaluated are “sustainable grassland management” (for C1 and C2), “soil fertilization” (C1 and C2), “weed control in grasses and Crops” (C1), “veterinary prevention and care” (C1 and C2), “food safety” (C1 and C2) and “ecological farm management” (all Cs). While C3 had values above 50% for all of these indicators except “ecological farm management”, C1 and C2 have low values for these indicators principally due to the fact that farmers have not received the necessary training and advisory to be able to adhere to the organic regulations, despite the fact that the majority of LPU use traditional agricultural methods and few external inputs. Nevertheless, some indicators show potential viability of organic conversion of the LPU including “feeding management”, “pest control in grasses and crops”, “breeds and reproduction” and “animal well-being”, all of which showed viability for all three C

as well as “weed control in grasses and crops” for C2 and C3 and “food safety” for C3. The LPU of C3 show the greatest potential for organic conversion (61.5%), given that all indicators except for “ecological farm management” have intermediate to very high potential for conversion due to the high values of their variables. In summary, the values of ICOGAN range from intermediate to high. The values of ICOGAN found in this study are greater than those found for conventional livestock raising in the Frailesca and Marques de Comillas regions of Chiapas 48.0% and 53.3%, respectively which showed intermediate levels of viability.

In general, the level of approximation of the LPU evaluated to the organic model is a result of traditional management with low use of external inputs more than implementation of sustainable production technologies. If farmers modify their current form of production, so that, it concurs with organic production standards, they will have to wait for the necessary transition or conversion period to elapse in order to reduce to a minimum the residual effects of any agrochemicals previously used. Also, there is a need to train farmers to substitute capital-dependent technologies which degrade the environment with others that make efficient use of local resources, thereby allowing for maintenance of biological diversity and soil productive capacity (Mena-Guerrero *et al.*, 2009; Nahed-Toral *et al.*, 2013). In order to achieve sustainability of the LPU, farmers should review and follow the list of substances permitted, prohibited and restricted by organic regulations (Muller-Lindenlauf *et al.*, 2010).

Transition toward organic production: The transition period for a farm to be considered organic depends on the initial situation or base line; according to IFOAM (2018) this transition period ranges from 12-48 months. Farmers will be more likely to be able to transition to the organic model within the established period, if they are able to improve their farms with respect to the technical-economic and ICOGAN indicators for which they rated lowest, particularly with respect to, diversity of grazing units, use of local resources or those adapted to local conditions and knowledge of natural cycles, low use of external inputs and use of traditional agricultural technologies, artisanal quality of animal products, product quality control, lack of strategic alliances that foment transitioning to organic production and lack of consolidated productive chains that allow farmers to more directly market their products without involvement of intermediaries. These limitations currently impede LPU from marketing animal products in organic markets, significantly limiting prices and making it difficult to achieve sustainability (Nahed *et al.*, 2018). Furthermore, there is a need for decision makers to foment public policy which supports organic livestock production.

The importance of producing high quality animal products principally lies in their effect on health of consumers who increasingly demand food safety and environmental friendliness. Given consumer interest in recent years in safe, healthy, environmentally friendly food, certification of ecological animal products allows for competing with conventional animal products produced either in intensive or extensive systems. Additionally, certifying their products provides farmers with more opportunities to receive government economic incentives and support for infrastructure, both of which are necessary in the study region.

There is a need for public policy to provide financial support mechanisms, training and advisory; support organizational and management processes throughout the productive chain and implement an organic cattle raising development strategy (Nahed-Toral *et al.*, 2013) which includes a policy of agrifood health and safety that allows for financing organic certification costs in order to differentiate organic and conventional products implementation of government and non-governmental incentives that motivate farmers to adopt environmental friendly technologies including those which reduce greenhouse gas emissions which includes improved feeding practices that promote greater digestibility, thereby reducing emissions of enteric methane as well as improvement of animal health to produce more meat and milk with fewer animals and permanent support by researchers, government agencies and NGOs to develop alliances among actors farmers, marketers, processors and salespeople as well as promotion of animal products in local, national and international markets.

In this manner, meat, milk and cheese produced in the LPU evaluated as well as in the study region in general, may be certified as organic or otherwise of high quality to be able to be marketed in alternative market niches and benefit producers and consumers with which knowledge of product origin would contribute to farm families' food security, biological and social reproduction of the LPU and environmental sustainability (Nahed *et al.*, 2018).

Fomenting organic cattle raising in the study region:

Throughout the municipality of Tecpatan, organic livestock raising is a viable alternative due to the fact that for over 40 years, traditional farming methods which use few external inputs and approximate organic livestock raising practices have contributed to farm families achieving food security (Nahed-Toral *et al.*, 2010; Nahed *et al.*, 2018). The present study shows that the municipality of Tecpatan, inhabited principally by the Zoque ethnic group, presents favorable socioeconomic, technical and environmental conditions for fomenting organic livestock raising. With respect to socioeconomic conditions, the large number of peasants and other

small-scale farmers that raise livestock who vary with respect to their level of organization and willingness to convert to ecological cattle raising-may join the market niche of organic livestock raising and obtain greater income and other benefits which allow for improving their living conditions. In this manner, the LPU may continue their biological and social reproduction. With respect to cattle raising practices in this region, current forms of feeding management, soil fertilization, pest control in grasses and crops and livestock breeds and reproduction may also favor sustainable livestock raising. Finally, the region's severe environmental deterioration which has principally resulted from unsustainable agricultural practices justifies fomenting conversion of conventional cattle raising to organics.

Organic livestock raising is based on the principles of clean production and involves strategies that prevent contamination and contribute to provision of environmental services. For example, use of external inputs-such as chemical fertilizers and pesticides as well as fossil fuels-is minimal or absent. Organic LPUs include woody fodder shrubs and trees; grasses are planted in association with leguminous crops; animals used are cross-breeds or those adapted to the region and animals are grazed and provided with a significant proportion of fibrous fodder (Hersleth *et al.*, 2012). These measures generally, allow the LPU to avoid levels of greenhouse gases (nitrous oxide, methane and carbon dioxide) which exceed the system's capacity to absorb them. Furthermore, waste generation is minimized through maximum use of local resources, whereby inputs to the LPU are principally products of on-farm biological processes rather than fossil fuels and synthetic compounds (IFOAM, 2009). For example, in livestock raising systems based on free-range grazing with minimal external inputs, waste from production of balanced feed and synthetic fertilizers is avoided and locally available resources are reused and recycled, maximizing positive interactions among crops, livestock, silviculture and other components of the physical environment (Nahed *et al.*, 2018; Van-Wagenberg *et al.*, 2017).

Furthermore, organic livestock raising provides more environmental services on a landscape level than does conventional livestock raising. Practices used in organic livestock production, for example, through agrosilvopastoral systems-increase biodiversity through creation of complex habitats which favor a wide range of plants and animals, host a rich soil biota and maximize connectivity among forest fragments. In temperate climates as well as in tropical climates such as that of the study region, agrosilvopastoral systems serve as wildlife corridors that provide food and refuge for fauna. Their combination of grasses and trees helps retain soil and water as well as prevent erosion of watersheds and consequently soil nutrient loss.

CONCLUSION

The cluster analysis organized the 50 LPU evaluated into three groups: one (C1) with very low values for the technical-economic indicators as well as for eight of the ten indicators of the index; another (C3) with generally, high values for the technical-economic indicators as well as for the index and the other (C2) with intermediate values for both the indicators and the index. The high viability of organic conversion of the LPU of C3 is due to traditional management with low use of external inputs more than use of sustainable organic farming technologies.

The LPU of the three clusters appear to be very viable for conversion to the organic production model with respect to the indicators “soil fertilization” and “breeds and reproduction”. The LPU of C3 and C2 are very viable for conversion with respect to the indicators “feeding management” and “weed and pest control”. The LPU of C1 are highly limited for eight of the ten indicators and the indicators “veterinary prevention and care” and “ecological farm management” strongly limit conversion of all three clusters.

There is a need for all farmers of the LPU evaluated to strengthen the ten indicators and the variables that make them up, particularly with respect to the indicators “sustainable grassland management”, “soil fertility”, “veterinary prevention and care”, “food safety” and “ecological farm management”. We recommend that government agencies and NGOs implement a policy involving training, technical assistance and financial support, so that, livestock farms may rapidly transition toward organic certification, offer healthy products (meat, milk and cheese) and market their products at higher prices. The greater net margin and economic efficiency of C3 and C2 farms as compared to that of C1 farms allows for greater economic reinvestment in these LPU which could allow them to more quickly achieve organic certification.

C1 and C2 has an ICOGAN within intermediate potential of organic conversion. C3 has an ICOGAN which indicates high potential for organic conversion. There is a need for farmers and technical advisors to follow organic regulations with respect to management techniques as well as permitted, restricted and prohibited substances. Conversion of LPU to organic production depends on farmers further developing their abilities to manage sustainable agricultural systems through advisory, technical assistance and permanent financial support. There is also a need for all social actors involved to be committed to the conversion process as well as for significant changes in state and federal livestock raising policies which facilitate the LPU’s transitioning toward organic certification, so that, that may offer healthy products (meat, milk and cheese) and continue their biological and social reproduction while being economically viable.

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